Section 6. Technology

6.1 Introduction

The National Monitoring Strategy seeks to provide the direction for an ambient air monitoring network that can be more responsive to current and future needs of the network. This section focuses on areas of the ambient air monitoring program that are ripe for investment in new technologies. To provide input on the areas of technology that should be considered and how they might best be implemented, an ad-hoc workgroup of SLT and EPA representatives was formed. This workgroup met in a series of teleconference calls followed by a 3 day face-to-face meeting in October 2001. Areas considered include all hardware and software used in the monitoring, calibration, logging, transfer, storage, validation, and reporting of ambient air data. Through this process, three specific areas of technology were identified as most pressing for technology investment:

- PM continuous monitoring;
- data transfer and access of ambient monitoring data; and
- tools and training that support real-time or near-real-time public reporting of data.

There are many other technology needs within the ambient air monitoring programs, such as ozone QA optimization, use of web camera technologies, and toxics monitoring. These needs should also be considered; however, each has its own special set of issues. These issues will be discussed in this section and other sections of this document. For example, ozone QA optimization is also addressed in the QA section of the Strategy.

For each of these investments to be successful, not only is a financial commitment necessary, but also a dedicated approach of eliminating barriers to technology investment. For example, in order to invest in PM continuous monitoring, there needs to be a regulatory mechanism to allow for substitution of some of the FRMs with continuous monitors. Also, there may be provisions in the current regulations and guidance that are preventing the implementation of some of these technologies. Therefore, the following recommendations are made as mechanisms to accommodate the investment of these new technologies:

- support for a hybrid network of PM monitors that provides for a substantial divestment of filter-based monitoring and investment in continuous monitoring;

- a thorough examination of ozone monitoring quality assurance that would result in recommendations leading to greater efficiency in ozone monitoring QA;

- an examination of available telemetry systems to optimize data access and transfer;

- support for investment in data management systems at the state and local agency level that could lead to more efficient processing of data; and

- accommodation for each of these areas to be included in the grant process so that available grant monies can be used for these investments.

While the recommendations above may go a long way towards fostering implementation of appropriate technology investment, the list cannot comprehensively address every need in the immediate future or longer term. SLT's, along with EPA, should continue to define areas that are best suited for technology investment.

6.2 Background - State of Technology in Ambient Air Monitoring

The technologies used in the ambient air monitoring program cover all hardware and software used in the measurement, calibration, logging, transfer, storage, validation, and reporting of data. Figure 6-1 illustrates the flow of data from where it is produced to where it ends up being reported. Many of the areas identified are already using state of the art technologies. For instance, much of the gaseous criteria pollutants are measured using continuous monitors with automated features for calibration and data output. However, other areas, such as data transfer, are relying on technologies that may be outdated. In some cases a technology may be somewhat antiquated; however, because it is operating smoothly and satisfying the needs of the data users, it may not be an opportune area for investment.

Figure 6.1. Data flow in Ambient Air Monitoring Systems

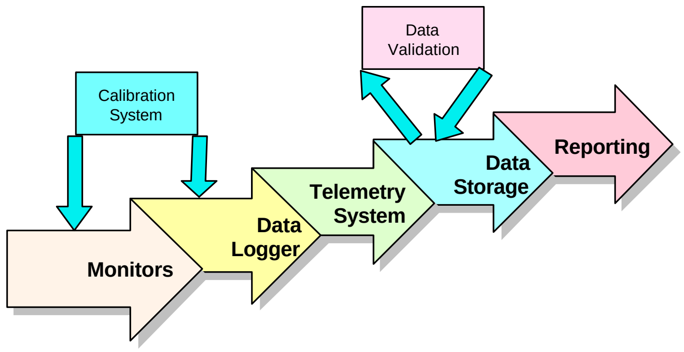


Table 6-1 breaks down an ambient air monitoring program into individual technology elements, summarizes the state of technology used in a typical ambient air monitoring program, provides initial recommendations for each technology element, and provides a qualitative assessment of the need for investment in each element.

Table 6.1. Data Flow in Ambient Air Monitoring Systems			
Technology Element	**State of Technologies used in typical Ambient Monitoring Program**	**Recommendations**	**Need for new Investment**
Gaseous criteria monitoring (O3, CO, NO2, SO2)	Continuous	May need to work towards lower detection limits. See methods section	low
Gaseous criteria calibration systems	Mixed - Everything from fully automated to manual	Move all agencies towards fully automated systems	medium
PM monitoring	Mostly filter based	Develop hybrid network of continuous and filter based monitoring to reduce dependency on filter network and optimize resources	high - for continuous monitoring
Data Loggers	Variety of loggers in use from ones implemented in the ‘80's to on-site PC’s acting as data loggers	Focus on desired performance capabilities, and compatibility with calibration and telemetry systems.	medium
Telemetry systems	Everything from low baud modems used on standard telephone lines to satellite, cable modem, DSL and other high speed internet systems.	Focus on performance needs of moving low interval data very quickly to support real time reporting and other data uses. Choose most optimal telemetry system depending on availability in area of monitoring.	high
Data Storage	Large variety of data storage procedures from State to State; including storage on PC’s, network servers, and mainframes.	No specific recommendations	medium - depends on agency. Diminishing cost of storage may be ripe for optimization
Data Validation	Variety of validation procedures in use. Some agencies rely on complete manual validation, others use combination of automated screening and manual validation.	Work towards use of systems with automated screening.	medium - depends on agency
Reporting	Most agencies have somewhat automated reporting systems for their continuous monitoring data.	Emphasize public reporting of data beyond ozone. Automate AQS reporting features.	medium - depends on agency

6.3 Areas of Investment

This section identifies each specific area of investment for the ambient air monitoring program. Any one air monitoring program may or may not already have invested in these areas. These areas have been identified due to either the heavy burden of already doing the work or because they are areas that data users have identified as being needed.

6.3.1 Monitoring

In general, continuous methods should be emphasized over manual methods. This is important for several reasons. On the resource side, continuous instruments are usually much less resource intensive to operate, provide more useful data for assessment of air quality throughout a day, have a higher sample frequency, provide for greater precision due to reduced human intervention, are easier to automate with respect to data delivery, and their data are easier to validate. On the information side, continuous data allow for real-time feedback to the public, as opposed to waiting days or weeks until filters are processed in a laboratory. The descriptions below provide the specific monitoring areas of investment being considered in this strategy.

6.3.1.1 PM Continuous Methods

A strong push for PM continuous methods is a major component of the Strategy. EPA has developed an ambitious continuous monitoring implementation plan that was borne out of requests from state and local agencies (specifically through SAMWG) and from the CASAC subcommittee on PM monitoring. Attachment 6.1 provides the continuous monitoring implementation plan, which is summarized below. Revision 2 of the plan is being developed to include recommendations of CASAC. Some of the major features of the PM continuous monitoring strategy include:

- support for a hybrid network of several hundred PM continuous monitors with a few hundred FRM samplers;

- using performance based criteria developed in the Data Quality Objective (DQO) process to determine the acceptability of PM continuous monitors in the individual networks that they are used; and

- a parallel approach for approval and applicability of methods with one option being more rigid and allowing approval of a continuous method for all monitoring objectives and a more flexible approach that allows for using these monitors for all monitoring objectives except the first order of comparison to the NAAQS.

The end goal of the PM continuous monitoring strategy is to have a PM monitoring network that can meet multiple monitoring objectives at lower cost.

PM Continuous Monitoring Implementation Plan Summary

An enlarged continuous PM monitoring network will improve public data reporting and mapping, support air pollution studies more fully by providing continuous (i.e., hourly) particulate measurements, and decrease the resource requirements of operating a large network of nearly 1200 filter-based reference particulate samplers. The continuous monitoring implementation plan provides recommended directional guidance to move forward in deploying a valued continuous PM monitoring program operated by SLTs. A range of topics is addressed, including relationships between continuous and reference measurements, performance analyses of collocated continuous and filter based samplers, recommended performance criteria, regulatory modifications, and identification of outstanding technical issues and actions to be taken in the near future.

The plan proposes a hybrid network of filter based and continuous mass samplers. The hybrid network would include a reduced number of existing Federal Reference Method (FRM) samplers for direct comparison to the National Ambient Air Quality Standards (NAAQS) and continuous samplers that meet specified performance criteria related to their ability to produce sound comparisons to FRM data. Two approaches for integrating continuous mass monitors are proposed to maximize flexibility for agencies: an expanded use of Correlated Acceptable Continuous Monitors (CAC), and a new Regional Equivalent Monitor (REM) program. The CAC approach would enable agencies to address any monitoring objective, other than ***direct*** comparisons to NAAQS for attainment and nonattainment designations, while the REM approach would serve any monitoring objective.

In either approach, if data produced by a continuous monitor differ from that produced by the reference method, then monitoring agencies should seek to optimize the continuous method to reduce those differences. If all established means to optimize the continuous method have been exhausted, and the differences in data from the reference method and continuous monitors are still not acceptable, then the continuous data can be adjusted to be more comparable to that of the reference method. Adjustments will be allowed for the REM utilizing either raw data alone for simple regression or a combination of raw data from the instrument and physical or chemical parameters as necessary for multi-variate regression, so long as these parameters can be appropriately controlled. For instance, ambient temperature is readily available and checked on a routine schedule against a temperature standard as it directly factors into maintaining active flow control of the instrument. For a CAC, any type of adjustment will be allowed with no limitation on the parameters that can be used. At sites operating a continuous instrument that is not collocated with a reference sampler, assumptions will have to be made about the adjustment that is appropriate to produce data that is comparable to a reference sampler. The general approach proposed in the plan is to determine geographical regions representing networks of sites or a sub-set of a network; for example, rural areas and small cities, where one adjustment is appropriate for all of the continuous measurements. There is flexibility in the approval of adjustments and regions associated with a CAC, whereas the adjustments and regions associated with the REM will be restricted and subject to an independent review through EPA's Office of Research and Development or a similar entity.

Three performance criteria are proposed to determine whether the adjusted continuous measurements are sufficiently comparable to be integrated into the $PM_{2.5}$ network. These criteria are bias, relative to a filter-based reference method, between -10% and +10%, measurement precision (i.e., data from two collocated continuous monitors) less than 20% coefficient of variance (CV), and an initial proposal for a correlation coefficient of 0.93 (e.g., squared correlation of 0.87) for a REM type monitor and 0.90 (e.g., squared correlation of 0.81) for a CAC type monitor. The precision and bias criteria are the result of a data quality objective (DQO) analysis that is based on data from the existing $PM_{2.5}$ network and an assumption that the annual $PM_{2.5}$ air quality standard is the principal decision driver. In a DQO analyses for the daily standard, continuous monitors, which provide what amounts to a daily sampling frequency were demonstrated to have less uncertainty around a potential decision than filter based referenced methods at lower sample frequencies, all other things being equal. Thus, the use of approved continuous monitors at sites near the daily standard should be an improvement over filter based samplers with lower sample frequencies. Also, the DQO result is conservative in that the goals estimate decision error rates for the "worst case" scenarios. In cases that are not "worst," the DQO approach allows for additional flexibility beyond the stated bias and precision goals. The correlation criteria identified provide an initial attempt to quantify a necessary minimal value for this statistic. These values were selected based on the empirical evidence of the current $PM_{2.5}$ continuous monitoring network and a DQO exercise to determine what observed correlation coefficient is acceptable for use with $PM_{2.5}$ continuous methods. These performance criteria preferably would be demonstrated by monitoring agency staff independently or in cooperation with instrument manufacturers under actual operational conditions, a departure from the very tightly controlled approach used for national equivalency demonstration. Continuous monitors would be validated periodically in recognition of changing aerosol composition and instrument performance.

6.3.1.2 Ozone Methods

Although a large network of ozone monitors exists in the United States, there may be opportunities to make better use of the ozone network. This could potentially involve several specific areas of technology associated with ozone monitoring, as identified below:

- opportunities to divest of some redundant urban monitoring and relocate those monitors in areas outside the urban environment in order to detect the spatial gradient of ozone. This is expected to be largely accomplished through the assessments performed across regional areas.

- a comprehensive review of how ozone monitoring quality assurance is performed. This should examine the regulations as identified in 40 CFR Part 58, Appendix A and the QA guidance in the “Red Book.” A review of how state and local agencies are performing QA in their agencies should also be performed. The review should provide recommendations for areas of divestment and investment in ozone monitoring quality assurance.

6.3.1.3 Web Camera Technologies

Many State and local air monitoring agencies have successfully implemented web cameras to illustrate the visual quality of the air. For example, the CAMNET site (http://www.hazecam.net/), implemented by NESCAUM, provides web accessible images of urban and rural scenic vistas at several sites throughout the northeast. The images have been used with air pollution data to communicate visibility and air quality. The relatively low cost of the technology combined with an effective medium for distribution of the data on state and local agency websites makes for an efficient way to communicate air quality to the public. With the growing interest in reporting and forecast ambient air quality to the public, the web cameras have become an important tool in supplementing these reports.

6.3.2 Information Technology

The areas of information technology currently run in most state and local agencies may be the most ripe for new investment. This is largely due to both the need for a national network of air monitoring that can be available in real-time to support public information needs of the data, and the substantial areas of improvements that have been made in information technology since most air monitoring stations were implemented. Although commercially available information technologies may be substantially more efficient than what are currently being used by many state and local agencies, there are a number of issues to consider, such as making the best choice for investment, costs of technical support, and how easy would it be to move to another generation of this technology once the current generation is outdated. This subsection identifies some of the key issues with each area of information technology supporting an ambient air monitoring program as well as desired performance capabilities of an information transfer system to serve Level 2 and 3 NCore sites.

6.3.2.1 Instrument to Datalogger

Most continuous monitors have the ability to output data at least two ways. For real-time or near real-time monitors, analog outputs usually have a DC voltage corresponding to a range of the concentrations. For example, in an ozone monitor, a 0 to 5 volt output might correspond to a 0 to 500 part per billion range. The analog output is fed into a datalogger that has been programmed to receive the DC voltage and interpret it as a concentration of ozone. A RS-232 or other output device may also be employed. These outputs can carry a substantial amount of information beyond the concentration value. For instance, operating temperature, light intensity, if applicable, and concentration range may all be carried in addition to the actual concentration. Despite the wealth of information that can be carried across an RS-232 connection, these connections are rarely used. The primary reasons for using DC voltage outputs over RS-232 connections are the simplicity of receiving the concentration data by DC voltage and the lack of standard formats for the fields among vendors for the RS-232 connections. Despite not using these other data available via the RS-232 connection, some of the information may actually be very useful for validating data and remote troubleshooting of instruments. With the cost of storing data becoming cheaper, having an archive of these data may be an effective way to improve this component of the ambient air monitoring program. In order to move from a network where most sites are connected by DC voltage to something that provides for more information, a number of issues need to be worked through. For instance, providing the data in a common format from multiple vendors, manufacturers would allow for dataloggers to be easily adopted to receive data from any of these monitors. Also, an examination of the existing and up and coming direct connections should be made (e.g., USB, ethernet, FireWire).

6.3.2.2 Datalogger to Database

Once data are on the datalogger at the ambient air monitoring station, they need to be sent to servers where they can be summarized and disseminated to data users. In most cases this will occur by using a server at the office of the state or local agency. The frequency of the transfers is usually dictated by the needs of the data user. For public information use, data may need to be sent to the server every hour of even more frequently. The conventional way to get data from the monitoring stations has been to poll each of the stations individually. With more widespread availability of the internet, pushing data from monitoring sites on a regular basis will be especially effective in mapping and public reporting of data.

6.3.3 Reporting

The need to provide data to a number of users will require multiple reports of the information. For example, the public may need a near real-time simple message that the air is “clean” or “moderate.” A health researcher or modeler may want a very detailed accounting of the available data in the shortest time intervals possible. Regulatory users generally want the data in the form that they can be compared to the NAAQS.

6.3.3.1 Public Reporting

The area of public reporting for air monitoring data may provide the largest number of users of data. This area has been growing rapidly in the last few years as a result of the increased availability of air quality reporting, especially for ozone. This is expected to continue for other pollutants. Specifically, PM public reporting is expected to increase as more agencies bring their PM continuous instruments on line and EPA’s AIRNOW program accepts and reports PM monitoring data.

6.3.3.2 AQS Reporting

Air monitoring data is to be supplied to AQS after it has been validated at the state or local agency level. In early 2002, EPA implemented its new AQS system. The new system is expected to have a lot more functionality than the previous mainframe system. This will be especially useful to casual users of the data who were previously unable to access air monitoring data from the mainframe system.

6.3.4 Summary of Desired Performance for Information Transfer Systems to Support National Core Network of Ambient Air Monitoring Stations

Currently, most agencies are using the same information technology systems to record and move data from ambient monitoring stations that were implemented in the 1980's. Due to incredible improvements in processing speed and storage capacity, as well as the throughput capabilities to move data, some information technology systems currently in use may be antiquated. If one considers future needs of a national core network (NCore) of ambient air monitoring stations, such as automated low level validation and national near-real time delivery of multi-pollutant data, very few systems as currently run can meet these needs. However, in some cases systems may be adaptable to desired performance capabilities simply by upgrading the telemetry or adding additional features to existing systems. Other systems may need to be replaced entirely to meet the needs of NCore. This section summarizes the desired performance capabilities of an information transfer system to serve Level 2 and 3 NCore sites.

6.3.4.1 Monitoring Objectives and Performance Criteria

To define the needed performance criteria of a state-of-the-art information technology system, a matrix of needs has been developed. This matrix considers an optimal information technology system, but is not intended to address what the individual components should look like. For instance, once low-level validated data for a specific time period were ready to leave the monitoring station, a number of telemetry systems may actually accomplish moving those data. By identifying the needed performance criteria of moving data, rather than the actual system to move it, monitoring agencies may be free to identify the most optimal system for their network.

Table 6-2 summarizes each of the major monitoring objectives of NCore, the lowest monitoring interval that can reasonably achieve supporting that objective, and how quickly a national set of those data are expected to be aggregated and made available to a user community. Since an information transfer system will need to support the monitoring objectives with the tightest performance needs, the minimum design criteria are summarized at the bottom of Table 6-2.

Table 6-2. Monitoring Objectives and Associated Performance Needs

Monitoring Objective	Monitoring Interval Needed	Availability of Aggregated National Dataset
Public Reporting - Air Quality Index (AQI)	Hourly data	Within an hour
Mapping	5 minutes to one hour.	Within an hour
Exposure	1 minute to one hour	Within an hour
Modeling - Empirical modeling to support forecasting efforts	5 minutes to one hour	Within an hour
NAAQS	Generally 1 hour or 24 hour data are needed	Generally not needed until fully validated by monitoring agency, if lower level validated data is available as per other monitoring objectives.
Minimum Need	**1 minute**	**Within an hour**

By focusing on two of the most critical elements of an information transfer system (i.e., a minimum sample period of one minute, and moving data to be aggregated nationally within an hour), it becomes apparent that utilizing state-of-the-art telemetry systems will play a critical role in information transfer systems for NCore. Much of the other performance needs that can be identified are associated with the datalogger and associated computer. Table 6-3 summarizes some of these additional performance needs. Once again, an attempt was made to only define performance and not design criteria.

Table 6-3. National Core Network (Level II and III) Information Technology Performance Needs

Performance Need	Performance Criteria	Notes
Sample Periods	1 minute, 5 minute, and 1 hour data	1 minute to support exposure, 5 minutes to 1 hour data to support mapping and modeling. 1 hour data for Air Quality Index reporting and NAAQS. Sample period may need to be higher for certain pollutant measurement systems depending on method sample period and measurement precision when averaging small time periods.
Data Delivery	- 15 minutes within network - 1 hour nationally	Delivery every 15 minutes of 3 sample intervals each 5 minutes a piece. Exposure data could be supplied at 1 minute intervals for episode monitoring and as needed.
Low Level Validation	- Last automated zero and QC check acceptable - Range check acceptable - Shelter parameters acceptable - Instrument parameters acceptable	Other low level validation may be necessary
Data Availability	- all qc data, operator notes, calibrations, and pollutant data within network - Low level validated pollutant data externally	Create log of all monitoring related activities internally. Allow only validated data to leave agency network.
Types of monitoring data to disseminate - externally	- continuous and semi-continuous pollutant data - accompanying meteorological data - associated manual method supporting data (for instance FRM sample volume).	
Additional data for internal tracking	- Status of ancillary equipment such as shelter temperature, power surges, zero air system	
Relevant site information	Latitude, longitude, altitude, land use category, scale of representativeness, pictures and map of area.	Other site information may be necessary
Remote calibration	Ability to initiate automated calibrations on regular schedule or as needed.	
Reviewing calibrations	- allow for 1 minute data as part of electronic calibration log	
Initialization of manual collection methods	Need to be able to remotely initiate these or have them set at an action level from a specific monitor	

6.3.4.2 Other Performance Considerations

While some of the desired performance criteria can be identified in units such as sample period or data delivery time, others are more qualitative in nature. The following list identifies some of the other important considerations of an information transfer to support NCore:

- Allow for network time synchronization of all monitoring stations;
- Have battery back-up, such as a UPS, to ensure no data loss during power outage;
- Have information transfer system be self-initializing so that if power is interrupted (even with a UPS) the system will go back on-line;
- Provide graphical display of data;
- Provide math operations of data; and
- Automate AQS processing for NAAQS data after full validation in re-engineered format.

6.3.4.3 Optimizing Costs of Telemetry Systems to Support NCore

Although there needs to be an initial investment in upgrading information technology systems to support NCore, there is an expectation that the added value to the program by enhancing the timeliness and frequency of data delivery will more than account for the cost. Also, since the performance criteria, presented in this section, lend themselves to utilizing state of the art telemetry systems, such as high speed internet and satellite, there will no longer be a need for leased land lines to support low speed modems.

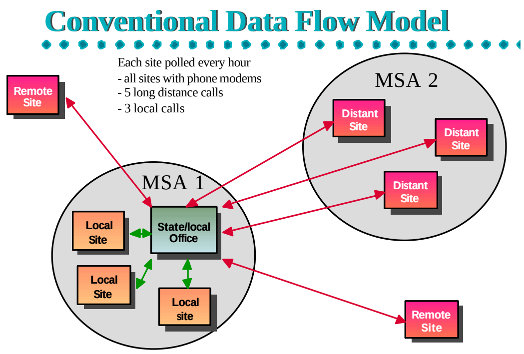


Figure 6.2

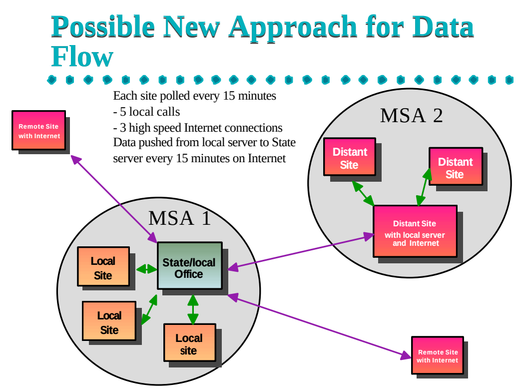


Figure 6.3

Ironically, many options for state-of-the-art telemetry systems are lower in cost than conventional systems. However, due to the cost and burden of implementing a new system, many monitoring agencies are reluctant to pursue this kind of a project. Consider the conventional data flow model in Figure 6.2 where there are five long distance calls each time the network is polled.

Now consider a possible new approach illustrated in Figure 6.3 which utilizes a combination of modems and high speed internet with no long distance calls. The savings from avoiding long distance calls can more than make up for the cost of the internet connection and local phone systems. Then the cost of frequent polling can be substantially reduced.

6.4 Issues

Despite the need to invest in many areas of the ambient air monitoring program, investing blindly may never result in an improved system. Some concerns that have been brought to the attention of the Technology Workgroup, from both within the group and external to it, are identified below. As appropriate, some possible solutions to each of these issues are also presented:

- Making the right choice for a technology. For any one type of technology, there may be several choices to consider. The most cost-effective choice right now may be outdated in a year. Making the right choice needs careful consideration and, even then, the choice may still not be correct.

- Transition from current to new technology. Need to consider things such as downtime of systems and a contingency plan if new systems fail.

- Training of staff. New technologies may require a higher level of expertise than the old system it was replacing. Need to adequately plan for major shifts in technology.

- Technical service. Need to consider what, if any, service plan would accompany any new technology. This may affect the true cost of the technology. Also, need to consider the responsiveness of technical service.

- Use of proprietary software. Need to consider the issues regarding the use of software that is not in the public domain.

- Ability to transfer to new technologies at a future time. Agencies need to be careful to select technologies that do not prevent them from selecting a newer technology down the road.

- Identification of appropriate technical specifications to be included on purchase requests so that air monitoring agencies make the right purchase of equipment. This is especially important regarding technologies that may have similar features; however, if the lower cost product is inferior, it may lead to substantially greater problems to the end user. If purchasing agents are given an appropriate amount of detail in the technical specification, selection of the inferior technology may be avoided.

6.5 Recommendations

From a technology perspective, the following summarizes the recommendations:

- support a hybrid network of PM monitors that provides for a substantial divestment of filter based monitoring and investment in continuous monitoring;

- optimize gaseous pollutant quality assurance, including automation of routine calibrations at all sites;

- clarify QA requirements when utilizing technologies for QA ptimization;

- implement state-of-the-art information technology systems that can provide data routinely in five-minute to one-hour intervals, with one-minute intervals for episodes, and be aggregated nationally within an hour;

- support investment in data management systems at the SLT level that could lead to more efficient processing of data; and

- accommodate, to the degree feasible, each of these areas to be included in the grant process so that available grant monies can be used for these investments.

DRAFT

Revision 2

June 21, 2002

CONTINUOUS MONITORING IMPLEMENTATION PLAN

Table of Contents

List of Abbreviations and Terms

AQI	Air Quality Index - An numerical and color coded index for reporting timely air quality to the public for five major pollutants: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide.
Bias (total)	The systematic or persistent distortion of a measurement process which causes errors in one direction.
BAM	Beta Attenuation Monitor - A monitor that uses a source and detector of emitted beta particles to determine the collection of particulate matter.
CAC	Correlated Acceptable Continuous *(as currently applied)* - A continuous $PM_{2.5}$ monitor collocated with a FRM having sufficient comparability to allow for a reduction in sample frequency of the FRM from daily to 1-in-3 days.
CAMM	Continuous Ambient Mass Monitor - A monitor that measures changes in pressure drop across a filter tape with particulate matter collected on it to determine the concentration of fine particulate.
CASAC	Clean Air Science Advisory Committee - A group charged with statutorily mandated responsibility to review and offer scientific and technical to the Administrator on the air quality criteria and regulatory documents which form the basis for the National Ambient Air Quality Standards.
DQO	Data Quality Objectives - Are qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential errors, that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
FEM	Federal Equivalent Method - A method for measuring the concentration of an air pollutant in the ambient air that has been designated as an equivalent method in accordance with 40 CFR Part 53.
FRM	Federal Reference Method
Measurement Precision (total)	A measure of the mutual agreement among individual measurements of the same property, usually under prescribed similar conditions, expressed generally in terms of the standard deviation.
Primary Monitor	Identifies one instrument as the sanctioned monitor for comparison to the

	NAAQS when there are multiple instruments measuring the same pollutant at the same site.
REM	Regional Equivalent Monitor - A potential new type of equivalent monitor being proposed in this document that would be limited geographically in its approval to where its performance has been successfully demonstrated.
SAMWG	State Air Monitoring Working Group
SES	Sample Equilibration System - A technology utilizing a Naphion® dryer that allows sample flow streams to be conditioned to low humidity and temperature.
STAPPA/ALAPCO	State and Territorial Air Pollution Program Administrators / Association of Local Air Pollution Control Officers
TEOM	Tapered Element Oscillating Microbalance - A particulate matter continuous monitor that utilizes an inertial balance which directly measures the mass collected on a filter by measuring the frequency changes on a tapered element.

Executive Summary

An enlarged continuous PM monitoring network will improve public data reporting and mapping, support air pollution studies more fully by providing continuous (i.e., hourly) particulate measurements, and decrease the resource requirements of operating a large network of nearly 1200 filter-based reference particulate samplers. This document provides recommended directional guidance to move forward in deploying a valued continuous PM monitoring program operated by State and local agencies and tribal governments. A range of topics are addressed, including relationships between continuous and reference measurements, performance analyses of collocated continuous and filter based samplers, recommended performance criteria, regulatory modifications, and identification of outstanding technical issues and actions to be taken in the near future.

This plan proposes a hybrid network of filter based and continuous mass samplers. The hybrid network would include a reduced number of existing Federal Reference Method (FRM) samplers for direct comparison to the National Ambient Air Quality Standards (NAAQS) and continuous samplers that meet specified performance criteria related to their ability to produce sound comparisons to FRM data. Two approaches for integrating continuous mass monitors are proposed to maximize flexibility for agencies; an expanded use of Correlated Acceptable Continuous Monitors (CAC), and a new Regional Equivalent Monitor (REM) program. The CAC approach would enable agencies to address any monitoring objective, other than ***direct*** comparisons to NAAQS for attainment and nonattainment designations, while the REM approach would serve any monitoring objective.

In either approach, if data produced by a continuous monitor differ from that produced by the reference method, then monitoring agencies should seek to optimize the continuous method to reduce those differences. If all established means to optimize the continuous method have been exhausted, and the differences in data from the reference method and continuous monitor are still not acceptable, then the continuous data can be adjusted to be more comparable to that of the reference method. Adjustments will be allowed for the REM utilizing either raw data alone for simple regression or a combination of raw data from the instrument and physical or chemical parameters as necessary for multi-variate regression, so long as these parameters can be appropriately controlled. For instance, ambient temperature is readily available and checked on a routine schedule against a temperature standard as it directly factors into maintaining active flow control of the instrument. For a CAC, any type of adjustment will be allowed with no limitation on the parameters that can be used. At sites operating a continuous instrument that is not collocated with a reference sampler, assumptions will have to be made about the adjustment that is appropriate to produce data that is comparable to a reference sampler. The general approach proposed in this document is to determine geographical regions representing networks of sites or a sub-set of a network; for example, rural areas and small cities, where one adjustment is appropriate for all of the continuous measurements. There is flexibility in the approval of adjustments and regions associated with a CAC, whereas the adjustments and regions associated with the REM will be restricted and subject to an independent review through EPA's Office of Research and Development or a similar entity.

Three performance criteria are proposed to determine whether the adjusted continuous measurements are sufficiently comparable to be integrated into the $PM_{2.5}$ network. These criteria are bias (relative to a filter-based reference method) between -10% and +10%, measurement precision (data from 2 collocated continuous monitors) less than 20% coefficient of variance (CV), and a correlation coefficient of 0.93 (squared correlation of 0.87) for a REM type monitor and 0.90 (squared correlation of 0.81) for a CAC type monitor. The precision and bias criteria are the result of a data quality objective (DQO) analysis that is based on data from the existing $PM_{2.5}$ network and an assumption that the annual $PM_{2.5}$ air quality standard is the principal decision driver. In a DQO analyses for the daily standard, continuous monitors, which provide what amounts to a daily sampling frequency were demonstrated to have less uncertainty around a potential decision than filter based referenced methods at lower sample frequencies, all other things being equal. Thus, use of approved continuous monitors at sites near the daily standard should be an improvement over filter based samplers with lower sample frequencies. Also, the DQO result is conservative in that the goals estimate decision error rates for the "worst case" scenarios. In cases that are not "worst," the DQO approach allows for additional flexibility beyond the stated bias and precision goals. The correlation criteria identified provide an initial attempt to quantify a necessary minimal value for this statistic. These values were selected based on the empirical evidence of the current $PM_{2.5}$ continuous monitoring network and a DQO exercise to determine what observed correlation coefficient is acceptable for use with $PM_{2.5}$ continuous methods. These performance criteria preferably would be demonstrated by monitoring agency staff independently or in cooperation with instrument manufacturers under actual operational conditions, a departure from the very tightly controlled approach used for national equivalency demonstration. Continuous monitors would be validated periodically in recognition of changing aerosol composition and instrument performance.

A parallel effort to reduce the number of required FRM samplers nationally is under consideration. This effort may provide the divestment needed to generate operational resources to stimulate deployment of continuous mass samplers.

Section 1. Introduction

This document presents a proposal for enhancing the continuous particulate matter monitoring in the air monitoring networks operated by State and local agencies and tribal governments. The document addresses a range of topics including recommended performance requirements, regulatory modifications, and identification of outstanding technical issues and actions to be taken in the near future.

EPA is working with the Clean Air Science Advisory Committee (CASAC) technical subcommittee on particle monitoring; State and local agencies and tribal governments; and consortiums of State and local agencies on a strategy to enhance deployment and utility of continuous fine particulate mass monitors. This document is an important step in this cooperative effort as it provides a basis for comment on our intended approaches. Subsequent regulatory changes will be necessary to implement the directions in this implementation plan. Comments are welcome from all interested stakeholders on this document as well as the national air monitoring strategy it is intended to support.

The reader should be aware that the concepts and elements incorporated in this plan are singularly and collectively complex therefore creating a communications challenge. Other approaches were considered, but the potential drawbacks of a simplistic approach were not acceptable. That is, it would have been easy to develop a rigorous non-flexible program easily communicable but conveying little motivation for deployment. Similarly, a program without constraints would likely compromise data quality and interpretability. Thus, a decision was made to accommodate both flexibility and data comparability at the expense of developing and communicating a complex program.

The development of "acceptable" relationships between FRM measurements and continuous monitors is stressed throughout this document. The reason for this is that so many objectives relate to the FRM measurement (e.g., NAAQS comparisons, air quality index reporting, air quality model application). In many instances, there is no technical reason to expect comparability between disparate measurement approaches. Such comparability is desired given the utility of relating continuous measurements to a wealth of existing FRM data and to incorporate a reference marker. The downside of this approach is that the value of an FRM measurement is assumed or inferred to be greater than that of a candidate method, when in some cases the candidate method may better reflect "true" characteristics of an aerosol. This topic is addressed in more detail in Section 7.

Background

EPA is motivated to develop the continuous monitoring program by the need to improve public data reporting and mapping, support air pollution studies more fully by providing continuous (i.e., hourly) particulate measurements, and to decrease the resource requirements of operating a large network of filter-based particulate samplers. This document also addresses an important gap in technical guidance for the continuous particulate matter program, created in part by a strong emphasis to date on compliance (FRM) and chemical speciation sampling.

Approximately $170 million has been directed toward the deployment and operation of the $PM_{2.5}$ network since July 1997, and the $PM_{2.5}$ network continues to operate at a cost of $42 million annually. The majority of the annual expenses are for the operation and maintenance of the FRM samplers, $26.5 million. The introduction of continuous particulate matter monitors capable of addressing multiple objectives with reduced operator burden could produce desired network efficiencies. For example, the cost of operating a FRM sampler on a 1-in-3 day schedule for a year is approximately $19,000 (including operations, maintenance, data management, filters, and quality assurance audits). The cost of operating one of the available continuous (hourly) particulate matter samplers is approximately $8,000. EPA does not expect that all FRM samplers will be replaced; however, significant resources can be impacted by the use of more continuous samplers in lieu of some FRM's.

Assessments of existing criteria pollutant networks are being conducted as part of a separate but parallel National Air Monitoring Strategy effort. These assessments are providing direction for reducing the current number of $PM_{2.5}$ FRM based on observed spatial redundancy (due to relatively broad homogeneous fine aerosol behavior throughout the eastern United States) and related factors. Such divestment in filter based methods is needed to support integration of a more comprehensive continuous mass network, as well as preparing for future coarse particulate monitoring requirements. This comprehensive air monitoring strategy also has defined progress in continuously operating PM monitors as a priority for implementation.

Over the last four years, many monitoring agencies have expressed a strong desire for the development and acceptance of continuous methods for use as compliance samplers (i.e., federal equivalent methods). This sentiment has been expressed in a number of venues including the Air and Waste Management Association PM2000 Conference; through the STAPPA/ALAPCO Monitoring Committee and the Standing Air Monitoring Work Group (SAMWG); and the CASAC Technical Subcommittee on Particle Monitoring. The CASAC Technical Subcommittee on Particle Monitoring met on January 22, 2001 in a workshop session dedicated to continuous particulate matter monitoring. As a result of that workshop, EPA wrote the first draft of this implementation plan which was released in October of 2001. After presenting the concepts of this implementation plan to SAMWG and the National Monitoring Strategy Ad-hoc Technology workgroup, revision 1 of this document was released in January of 2002. On January 28, 2002, the subcommittee met to listen to presentations and comments on revision 1 of this implementation plan. As a follow up to that meeting, CASAC produced a letter report to EPA on March 1, 2002 (EPA-SAB-CASAC-COM-01-003). This version (revision 2) of the Continuous Monitoring Implementation Plan has been edited to take into account the advice of the Subcommittee, further work utilizing the DQO process and an ever-growing $PM_{2.5}$ continuous monitoring data set. The document provides further details on EPA's proposal to enhance continuous PM monitoring. The approach utilizes the data quality objective process to develop continuous monitor performance specifications. State and local agencies and tribal governments would have a set of parallel options through a new REM program and an modification of the existing CAC monitors provision.

The principal challenge implied within this document is maintaining an acceptable balance between data quality and technological progress. The promulgation of the 1987 PM_{10} standards included a performance-based approach to the acceptance of PM_{10} methodology. The current

$PM_{2.5}$ monitoring network has achieved relatively high data quality[1] due in large measure to the requirement of design-based methods (i.e., monitors with virtually identical components) and a thorough quality assurance program that followed through on a cycle of planning (data quality objectives), implementation (field/laboratory quality control), data assessment and reporting tasks. Risk in compromising data quality will emerge as an assortment of technologies are accommodated in the network. Consequently, the success of this program will rely not only on the initial data quality objective planning steps, but through a commitment to conducting the remaining quality assurance tasks and retaining the flexibility to take appropriate action in the use of data when systematic failures are encountered within the quality assurance system.

Document Layout

Section 2 examines the available collocated FRM and $PM_{2.5}$ continuous monitoring data. This examination illustrates both the successes and challenges of implementing PM continuous monitors. Sections 3 and 4 detail the applicability of the CAC monitors and the REM including testing requirements and the approval process. Section 5 focuses on network design emphasizing the suggested hybridization of FRM and continuous particulate monitors, and proposing a new minimum number of required $PM_{2.5}$ FRM sites. Section 6 provides the performance standards for using PM methods and a description of the data quality objective process utilized to derive the goals for precision and bias as well as a separate but related effort for a minimum correlation coefficient. The data quality objective process recognizes a number of variables such as measurement precision, population precision, sample bias, sample frequency, a 3-year standard, and sample completeness in order to predict the confidence in a decision around an annual average and a daily standard. Section 7 addresses the use of statistical transformations for each category of continuous methods. The use of such transformations need careful consideration in terms of number of variables, frequency of adjusting, and spatial scale of applicability. Section 8 describes options for approval of methods across a spatial scale. This section details how a number of inputs such as aerosol composition using both monitored data and modeled data as well as overlaying this output with natural geographic boundaries, such as how State lines or city boundaries may be used. Section 9 provides design guidance on continuous monitoring methods. Section 10 identifies how this effort to enhance a network of continuous particulate monitors is linked to the national monitoring strategy. Section 11 provides a summary of the potential regulatory changes and schedule necessary to implement this plan. Section 12 provides a repository of issues and action items.

[1] "CY 2000 Quality Assurance Report of the $PM_{2.5}$ Ambient Air Monitoring Program," U.S.EPA Office of Air Quality Planning and Standards, October 2001.

Applicability

The scope and intention of this document is focused on addressing continuous particle mass monitors that provide in-situ sampling/analysis capability producing outputs that can be aggregated upward to 1-hour reporting periods (e.g., TEOM's and beta attenuation gauges). The approaches proposed rely on the use of the data quality objective process to produce quantitative performance standards. This process would in concept accommodate alternative particulate matter measurement approaches beyond the more traditional continuous mass methods, assuming performance standards are achieved. Such acceptable examples that might provide a useful alternative to the federal reference method include the use of a continuous speciation monitor alone (e.g., sulfate only) or in combination with multiple speciation monitors (e.g., carbon, nitrate, and sulfate), or other filter based methods that do not have current equivalency status (e.g., dichotomous sampler). The principles described in this document are not applicable to measurement systems beyond particulate matter (e.g., utilizing particulate matter measurements to replace ozone or other discrete gaseous measurements).

Section 2. $PM_{2.5}$ Continuous/FRM Relationships

Editors note for Revision 2:

The number of PM2.5 continuous monitors reporting data to the AIRS database continues to grow rapidly. As of April 15, 2002 there were 192 PM2.5 continuous monitors registered in AIRS. 168 PM2.5 continuous monitors had data reported to the AIRS database. Initial review of these data has occurred and the same general patterns appear to be holding with regard to geographic and seasonal performance. Due to the effort necessary for analyzing a data set of this size and timing of this document, a further analysis has not been provided for in this revision. Analysis of PM2.5 continuous monitor performance are expected to be made as part separate data evaluation efforts.

Introduction

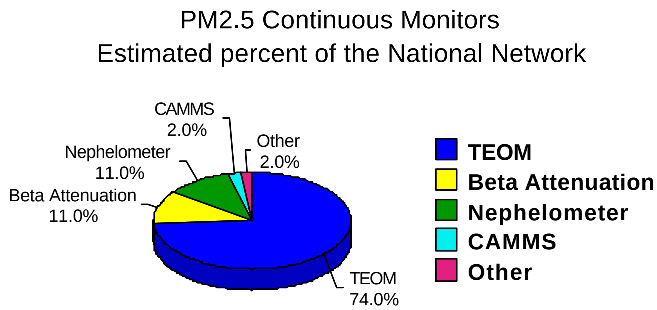
This section represents an initial effort to compile relational analyses between continuous and FRM data. Relationships between $PM_{2.5}$ continuous and FRM monitors are synthesized from a number of sources, including routinely collected data provided by State and local agencies and data from available field studies. The task of comparing $PM_{2.5}$ continuous data with FRMs was accomplished by averaging the hourly continuous mass data between midnight to midnight, to parallel the FRM operations. General information is provided first with a number of analyses presented later in this section. A more detailed set of analysis are presented in Attachment A.

General Summary

Continuous monitors track FRM data with varying degrees of success across the country, with a mix of seasonal and geographical patterns affecting behavior. Analyses to date are somewhat limited by the availability of relatively few formal field studies, and the current (and temporary) situation where only one $PM_{2.5}$ continuous method (the TEOM[2] operated at 50C) has been widely deployed (Figure 2-1). Despite these limitations, there is an emerging understanding that the best $PM_{2.5}$ continuous monitor choice may vary from one monitoring agency to the next. TEOMs operated at 50C appear to predict FRM measurements in locations where volatile losses are minimal. Examples include sites with sulfate dominated aerosols in the Southeast (the Carolinas and Georgia) throughout the year and northeastern and upper Midwest (Iowa and Michigan) locations during the summer. The prevalence of winter month underestimates in certain areas suggests that the TEOM operated at 50 C exacerbates volatile losses during cool conditions when the difference between operational and ambient temperature is greatest. Converting the 50C TEOM to a 30C TEOM with a Sample Equilibration System (SES) should reduce cool season volatile losses. Analyses comparing collocated 50 C and 30 C TEOMs with the SES and FRMs at sites in North Carolina and New York State indicate improved comparability to the FRM for the 30 C TEOM with the SES.

[2]Manufactured by Rupprecht & Pataschnick.

Figure 2-1 Percent of PM2.5 Continuous Methods used Nationally



The beta attenuation monitor (BAM)[3] is operated at several locations (second in number to the TEOM) throughout the western United States with a limited number of new locations in the east. The California Air Resources Board and other organizations sponsored a field study of several major $PM_{2.5}$ commercially available monitors indicating high performance of the BAM conducted during relatively volatile aerosol conditions.[4] EPA's Environmental Technology Verification Program (ETV) included two test sites; one in Pittsburgh, PA in the summer of 2000; and one in Fresno, CA in the winter of 2000-2001. This verification program included a number of $PM_{2.5}$ continuous monitors being deployed by State and local agencies including the BAM, the TEOM operated at 50C, the TEOM operated with the sample equilibration system at 30C, and the CAMMS[5]. While the verification reports do not offer conclusions as to the performance of the monitors, inspection of these reports indicates that the Met One BAM performed consistent at both test sites. The final verification reports from these field studies are available from the U.S. EPA web site.[6]

The Nephelometer is used at many sites in the Pacific Northwest. This monitor can have advantages over PM2.5 continuous methods with respect to its ease of operation. However, Nephelometers can have problems with high humidity and care should be taken to assure sample

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[3]Manufactured by Met One Instruments.

[4]Reference the CARB report here.

[5]Manufactured by Thermo Andersen.

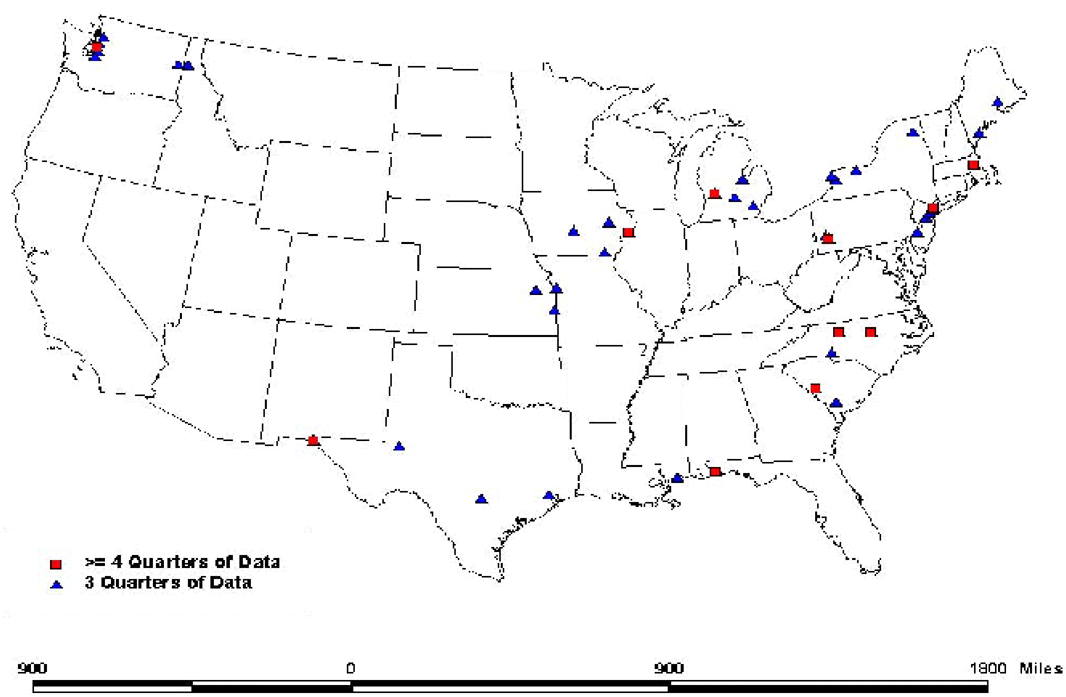
[6]Environmental Technology Verification Statements and Reports:
http://www.epa.gov/etv/verifrpt.htm#07

streams are conditioned so as not to have moisture interfere with the scattering output. There are several manufacturers of Nephelometers, so care also needs to be taken when comparing data from a monitor at one site to another. Although Nephelometers do not provide for a direct output of fine particulate concentration, they can be useful when calibrated against filter based methods to provide for diurnal and day to day signal of fine particulate.

Analysis of the Variety of Relationships for 47 Collocated $PM_{2.5}$ Continuous and FRM Sites

The AIRS database included 11 sites with at least a years worth of collocated $PM_{2.5}$ continuous monitoring and FRM data based on a Spring, 2001 retrieval. An additional 36 sites were included for analyses if they had at least 3 quarters of data with at least 11 valid collocated pairs per quarter for a total of 47 sites (Figure 2-2) forming the basis for the analyses presented in this section.

Figure 2-2 Map of 47 Sites used in $PM_{2.5}$ Continuous Monitors Analyses



Intercomparisons of FRMs and $PM_{2.5}$ Continuous Monitoring Data:

Of the 11 sites with at least 4 quarters of complete data, 8 sites used TEOM monitors with the factory installed correction factor applied for the entire data set. This factory installed correction factor adds 3 ug to the intercept and 3% to the slope for data coming from a TEOM. A table summarizing the range of concentration values from each of the FRM and continuous monitors at these sites is provided below:

Table 2-1 Concentration Ranges for 8 Sites with Collocated PM2.5 FRM and TEOM Monitors

MSA	Site ID	N	Primary Monitor Type	Concentration Range of Data (μg/m^3)						
				Mean	SD	Min	Q1	Median	Q3	Max
Aiken, SC - Augusta, GA	450370001	144	Continuous	14.50	6.42	1.37	9.85	13.46	18.88	34.75
			FRM	14.49	6.55	2.40	9.75	13.00	18.00	34.20
Davenport, IA - Moline - Rock Island, IL	191630015	453	Continuous	12.00	6.49	2.92	7.26	10.53	15.30	48.81
			FRM	12.81	7.31	2.30	7.30	11.50	16.90	46.70
Winston - Salem, NC	370670022	525	Continuous	16.23	8.05	2.66	10.29	14.45	20.95	64.02
			FRM	16.89	8.70	1.60	10.60	15.00	21.70	69.70
New York, NY	360050110	295	Continuous	15.40	9.26	4.69	8.85	12.85	19.24	85.38
			FRM	15.21	9.17	3.60	8.30	12.30	20.00	53.00
Pensacola, FL	120330004	214	Continuous	14.41	6.74	-17.7	9.90	13.02	17.94	45.83
			FRM	14.03	6.89	1.00	8.60	12.70	18.41	49.30
Pittsburgh, PA	420030064	344	Continuous	16.68	12.00	1.21	7.27	13.19	22.50	68.92
			FRM	20.87	13.39	3.10	11.00	17.20	26.55	78.50
Raleigh-Durham, NC	371830014	389	Continuous	15.02	6.89	2.78	10.00	13.66	18.98	45.88
			FRM	15.59	7.52	3.00	10.10	14.40	20.00	52.80

MSA	Site ID	N	Primary Monitor Type	Concentration Range of Data (μg/m³)						
				Mean	SD	Min	Q1	Median	Q3	Max
Seattle, WA	530330057	340	Continuous	13.30	6.39	3.38	9.08	11.87	15.48	44.42
			FRM	12.64	7.25	2.80	7.80	10.95	15.40	46.90

Inspection of Table 2-1 indicates that most of the sites appear to produce similar PM2.5 concentrations regardless of whether an FRM or TEOM is used. Only the Pittsburgh, PA site showed a large discrepancy between the mean of the FRM and PM2.5 continuous monitor. Due to this discrepancy, the Allegheny County monitoring staff were contacted to confirm the operation of the TEOM and use of default corrections factors. While the operation of the instrument was determined to be correctly identified, it was mentioned that the site is located in a community orientated location in close proximity to a large local source.

Scatter plots were produced for each of the 11 sites with at least a years worth of complete data. Data were plotted for each day where both a FRM value and a corresponding average 24-hour continuous $PM_{2.5}$ value were available. Separate plots for linear and log-normal concentrations were plotted for each site. The scatter plots can be separated into several categories: scatter plots with good agreement most of the time - illustrated by most points being on a straight line (Figures 2-3 through 2-6 and 2-9); scatter plots with a small but discernable amount of spread about the best fit line - as illustrated by a mild spread about the best fit line (Figures 2-7 and 2-8); scatter plots with good agreement part of the time and poor agreement in others - illustrated by a large increasing spread with concentration (Figures 2-10 and 2-11); and scatter plots that do not appear to correspond well with any pattern - illustrated by a large spread about the 1:1 relationship regardless of the concentration (Figures 2-12 and 2-13).

These first four figures represent sites in the southeastern United States where the $PM_{2.5}$ continuous monitor appears to track the FRM reasonably well:

Figure 2-3 Raleigh-Durham, NC

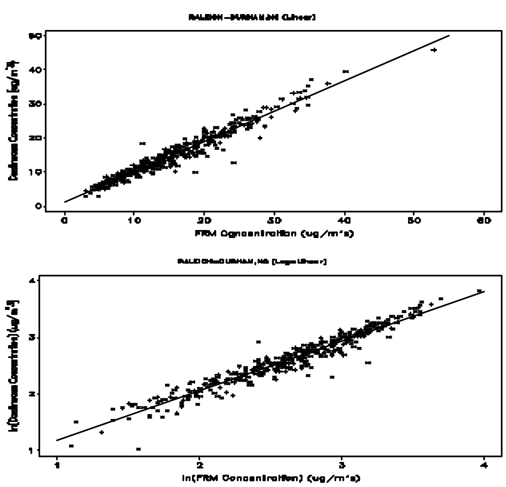


Figure 2-4 Winston-Salem, NC

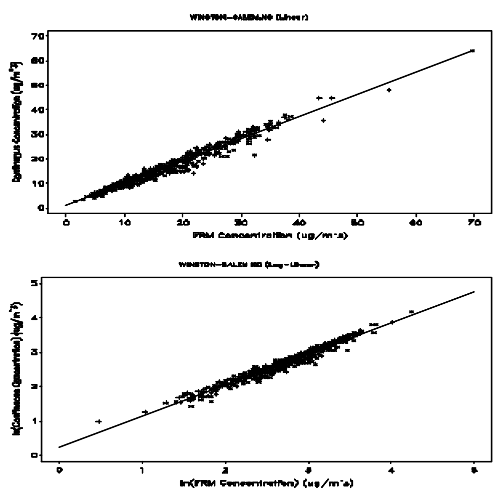


Figure 2-5 Aiken, SC - Augusta, GA

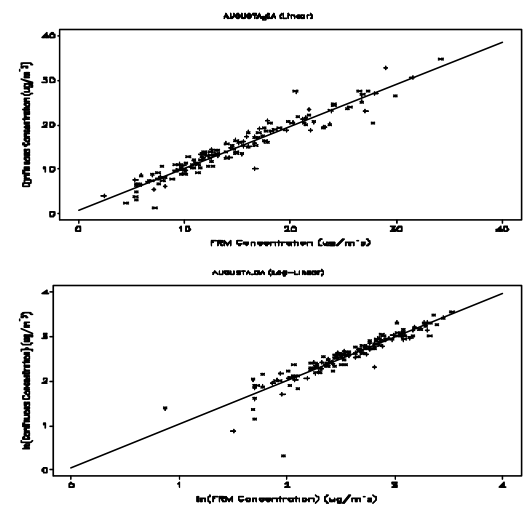
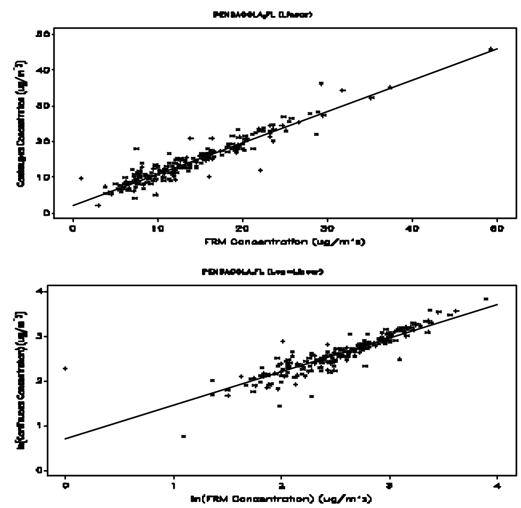


Figure 2-6 Pensacola, FL



The following scatter plots represent cities in the Northeast with some discernable spread about the best fit line, but not severely distorted.

Figure 2-7 New York, NY

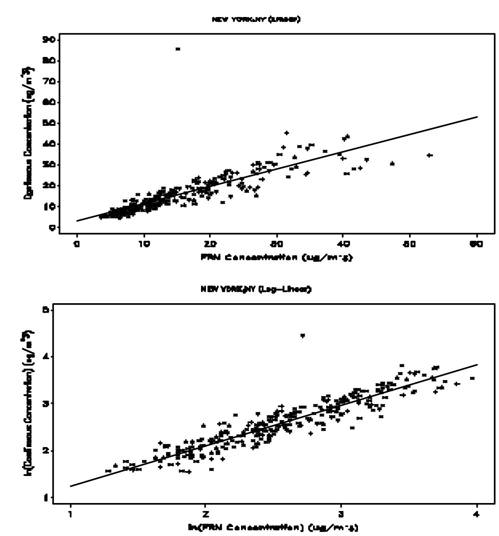
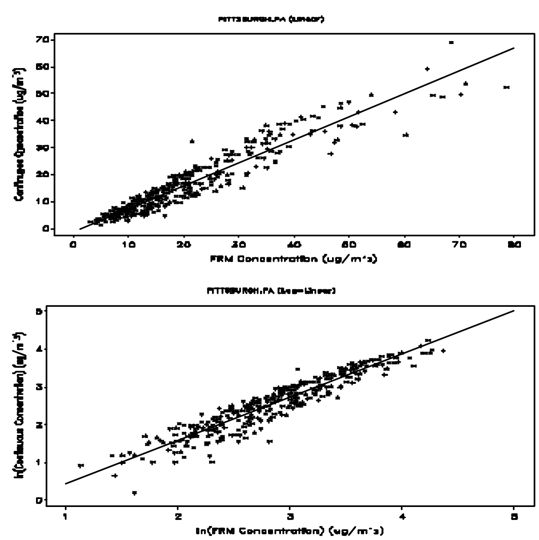
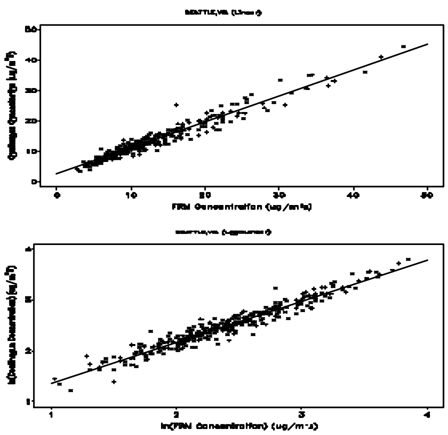


Figure 2-8 Pittsburgh, PA



The following figure is from a northwest site. The scatter plot shows a good fit about the best fit line.

Figure 2-9 Seattle, WA



These figures, using data from sites in the upper mid-west, represent a clear spread with concentration. This is likely an effect of seasonal aerosol changes.

Figure 2-10 Davenport, IA

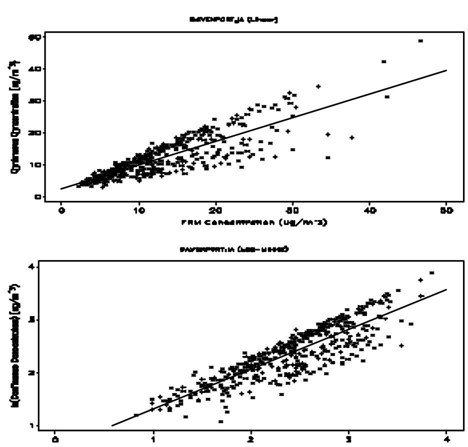
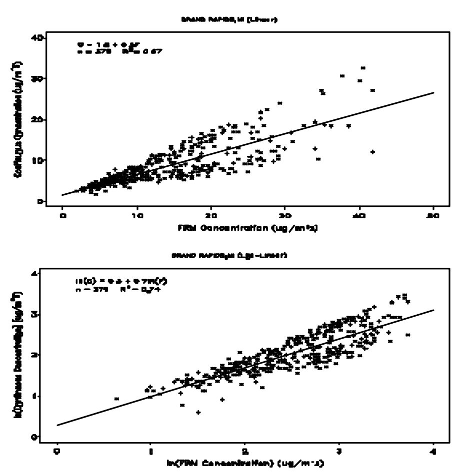


Figure 2-11 Grand Rapids, MI



These figures represent data from air sheds where the TEOM and FRM do appear to correspond well.

Figure 2-12 El Paso, TX

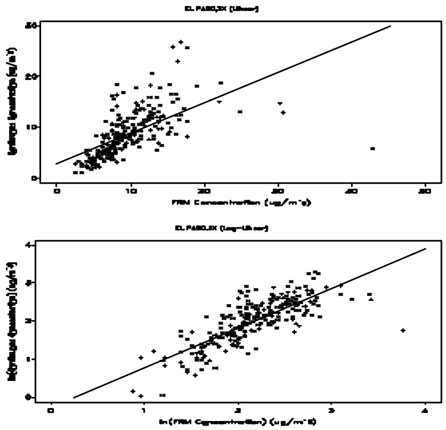
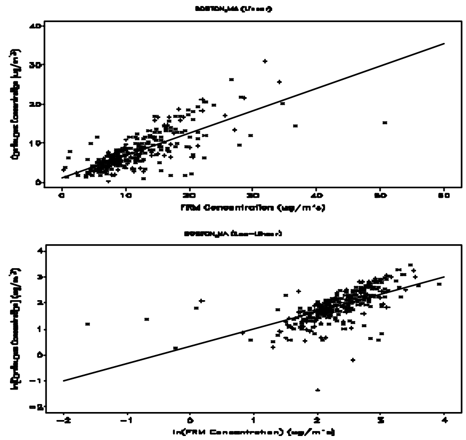


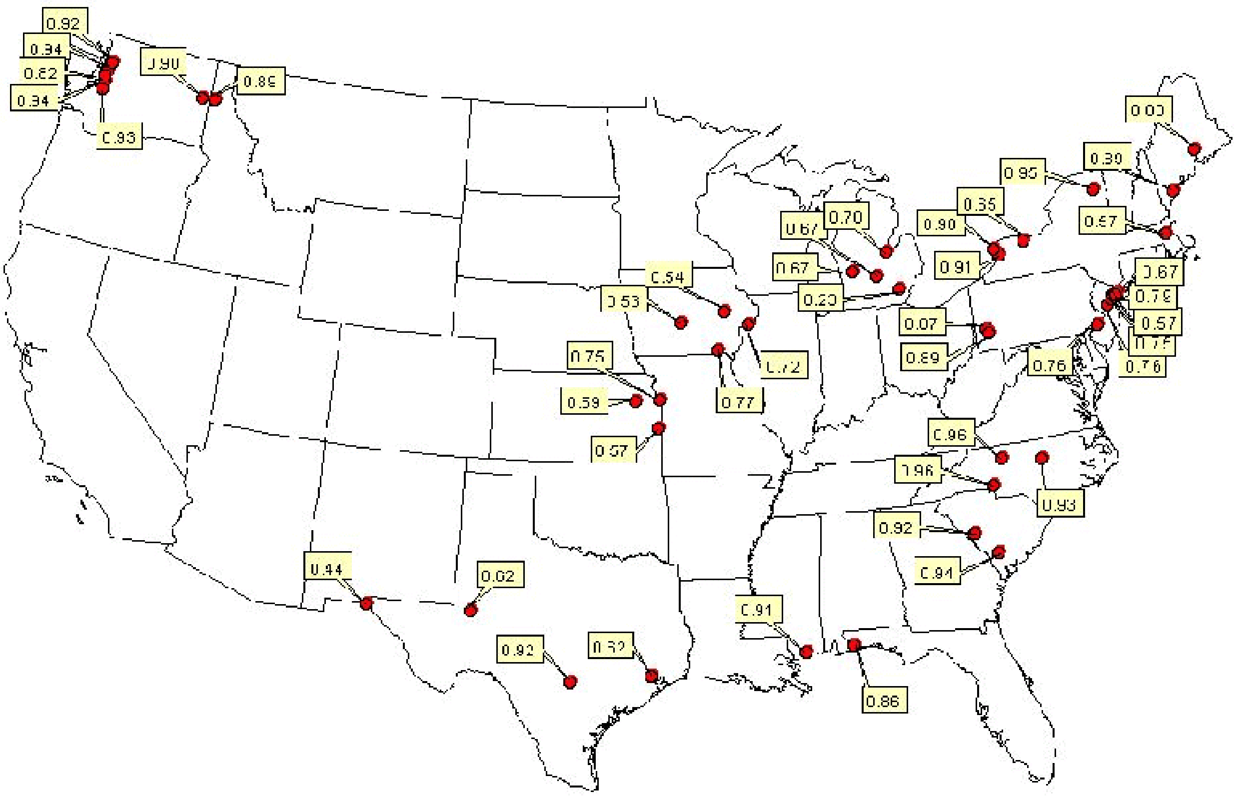
Figure 2-13 Boston, MA



Correlation between $PM_{2.5}$ Continuous Monitors and FRMs

Another way to look at the data is to evaluate the goodness of fit between a model using $PM_{2.5}$ continuous data to explain FRM measurements. The map below (Figure 2-14) illustrates the correlation coefficient (R^2) at each of the available 47 sites. All 47 sites are able to be used because a linear model will not affect the correlation regardless of whether a site specific model is used, the standard correction factors are applied or no model is used at all. The map also indicates that geographical area plays a large role in how high a correlation coefficient is observed. This is likely due to the aerosol encountered at specific sites, the concentration of fine particulate and an effect of the season. Areas exhibiting high correlation include the Southeast, Northwest and selective locations of the Northeast. Areas with poor correlation are likely the result of either regional scale winter time volatilization as demonstrated in Iowa and Kansas or micro-scale to urban-scale influences of local sources such as in Boston and El Paso.

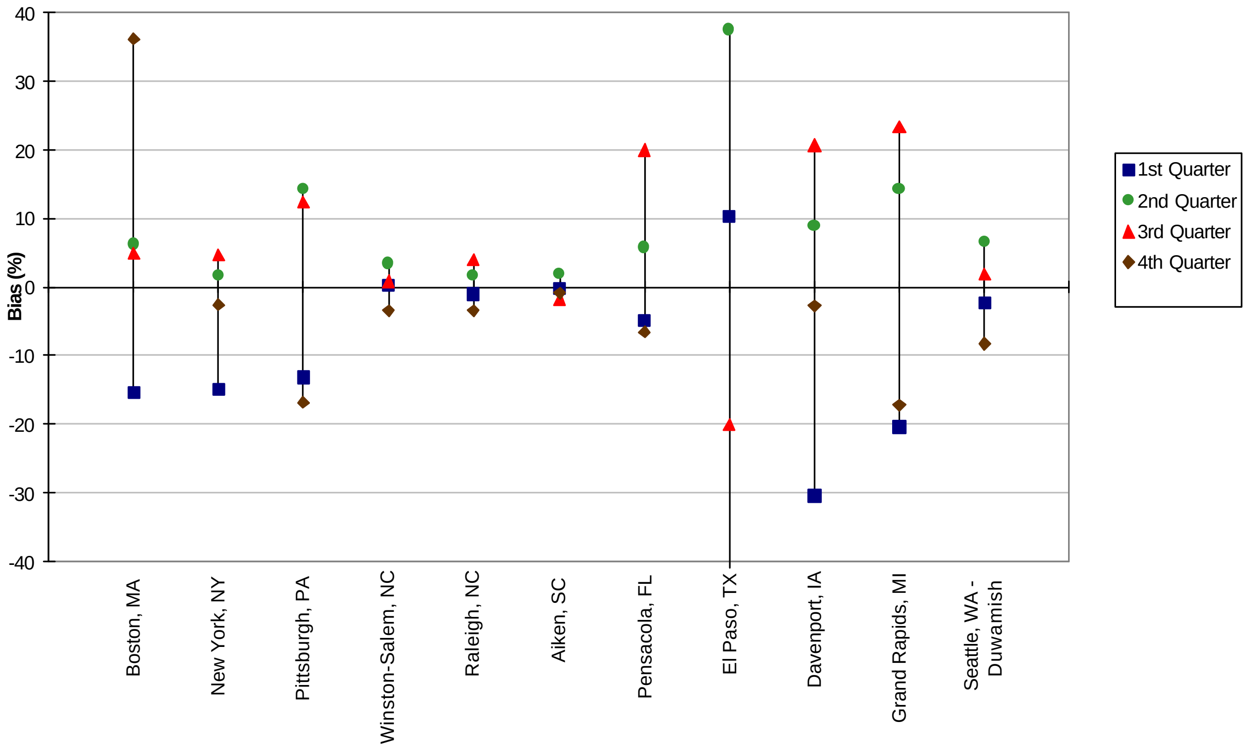
Figure 2-14 Correlation between FRMs and $PM_{2.5}$ Continuous Monitors



Bias by Season

In many air sheds across the United States the species and concentration of the aerosol encountered varies by season. Changes in the species and concentration of the aerosol can lead to changes in performance of a $PM_{2.5}$ continuous monitor. In the illustration below the spread of bias is presented for those sites with at least 4 quarters of complete data. Bias data were calculated by comparing the FRM and collocated continuous monitoring data for days when both instruments produced a valid 24 hour value. Since some monitoring agencies choose to use a standard correction factor in the reporting of their data while others did not, each set of data was first fit to it's own linear model and then the bias were calculated by quarter. Additional graphics depicting the bias by quarter for those sites without 4 complete quarters are available in attachment 1. The tighter the fit between season the better the opportunity to use that continuous instrument to produce FRM-like measurements. Generally, cooler quarters produced the largest negative biases. This is likely due to the larger difference between the operating temperature of the TEOM and the ambient temperature of the atmosphere. The relatively high operating temperature of the TEOM during these cooler months leads to evaporation of a portion of the aerosol that are collected on a filter based sampler.

Figure 2-15 PM2.5 Bias Data for TEOM Monitors by Quarter



Analysis of the Acceptability of the Relationship relative to the Data Quality Objective Process and Class III equivalency.

In the section above, a few of the sites appeared to have $PM_{2.5}$ continuous monitors that are replicating the FRM measurements very well with other sites not performing well and many sites in between. A site may be expected to replicate the FRM very well by virtue of having a scatter plot close to unity, a high correlation coefficient and a low bias. But with a variety of performances across sites, at what level should a site be considered acceptable? In this section data from 160 collocated FRM/FRM sites and 47 collocated $PM_{2.5}$ continuous/FRM sites are compared to various levels of the Data Quality Objective (DQO) process and the equivalency criteria. For the DQO criteria, precision and bias statistics are determined for each site and results are presented as a function of the percentage of sites that satisfied the criteria. For the equivalency criteria, linear regression is performed for each site and results are presented as a function of the percentage of sites that satisfied the criteria.

Table 2-2 Percentage of Collocated Sites meeting individual DQO and Equivalency Criteria

Criteria	160 Collocated FRM/FRM (% of sites meeting criteria)	47 Collocated FRM/Continuous Sites (% of sites meeting criteria)
Data Quality Objective		
Bias 5%	86.9	34.0
Bias 10%	97.5	53.2
Precision 5%	28.1	0.0
Precision 10%	68.8	12.8
Precision 20%	NA	61.7
Equivalency		
Slope (1±0.05)	77.5	91.5
Intercept (±1 µg)	82.5	97.9
Correlation ($0.97)	66.2	10.6

Interpreting Table 2-2 leads to several observations:

C Evaluations of the collocated FRM/FRM sites against the existing goals of ±10% bias and ±10% precision, indicate that precision is the limiting factor. Most (97.5%) of the sites meet the bias goal and 68.8 % meet the precision goal. As will be demonstrated in section 6, bias strongly influences the uncertainty of a 3 year mean, while precision has little effect due to the large number of samples in 3 years of data. Therefore, we have confidence that the FRM network is performing well, as indicted by 97.5% of the sites meeting the bias statistic.

C Evaluating the FRM/FRM sites against the existing criteria for Class III equivalency[7] indicates that correlation is the limiting factor with 66.2% of the sites passing. That's important since we believe we have a well-operating $PM_{2.5}$ FRM network; however, over one-third of the sites would fail the Class III equivalency testing criteria. If a collocated network of FRM cannot largely meet the

[7] 40 CFR 53

equivalency criteria, it will be very difficult for a network of FRMs collocated with $PM_{2.5}$ continuous monitors to meet this criteria.

- Evaluations of the collocated FRM/continuous sites against the existing goals of ±10% bias and ±10% precision indicate that precision is also the limiting factor with 53.2 % of the sites meeting the bias goal and only 12.8 % meeting the precision goal. As mentioned above and demonstrated in section 6, bias strongly influences the uncertainty of a 3-year mean, while precision has little effect due to the large number of samples in 3 years of data. If the precision goal could be reduced to ±20%, then 61.7% of the sites in the analysis would have satisfied this criteria. Although an even less stringent precision goal could potentially be chosen, bias has now become the limiting factor for performance of the continuous monitors. While precision could potentially be relaxed and we would still have a high degree of confidence in the 3 year annual mean, the need to monitor for other monitoring objectives necessitates controlling precision to some degree. A detailed explanation of the DQO process will be explained in section 6.

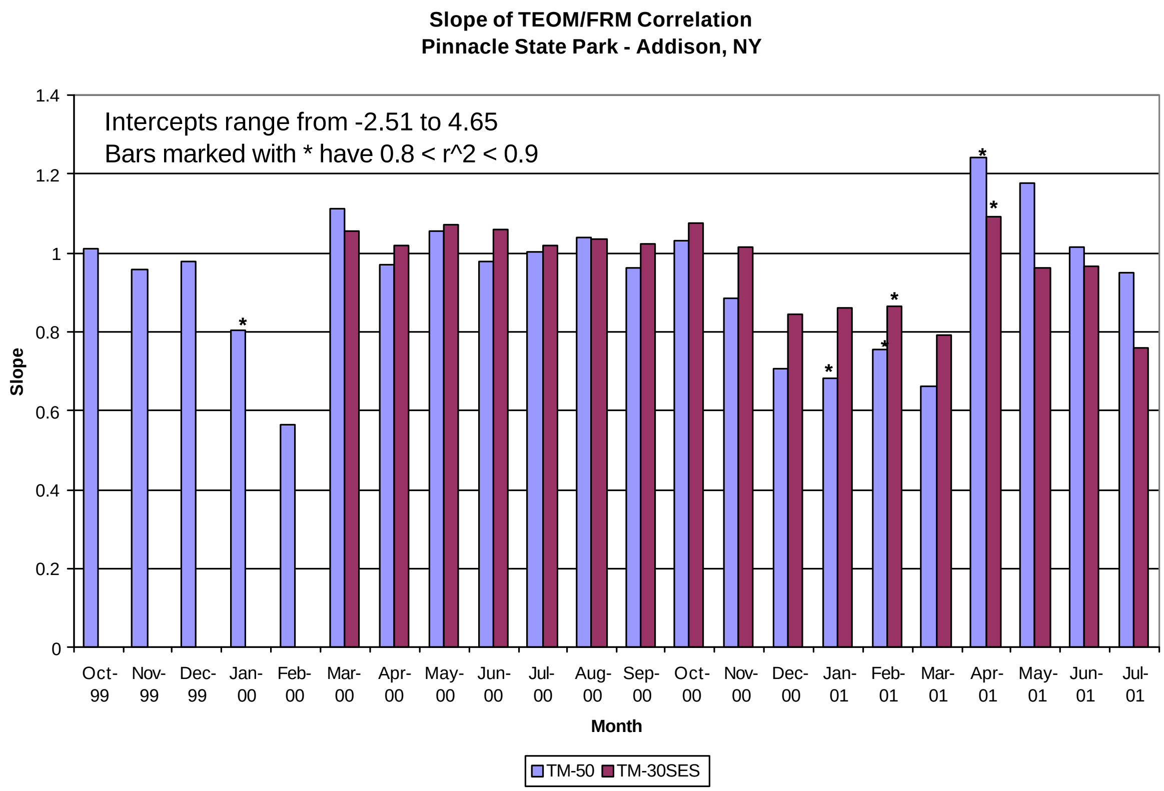
- Evaluating the FRM/continuous sites against the existing criteria for Class III equivalency indicates that correlation is the limiting factor with 10.6% of the sites passing. If it can be demonstrated that the continuous monitors are producing FRM-like measurements that meet the goals established in the DQO process rather than the equivalency criteria, than the correlation criteria becomes irrelevant.

Note: In addition to this analysis the EPA has produced assessments of the quality of the $PM_{2.5}$ monitoring program for the currently operating FRMs for calendar year 1999 and 2000. The calendar year 1999 report is final and can be reviewed on-line at the EPA web site: http://www.epa.gov./ttn/amtic/. The calendar year 2000 report is in review and a draft copy can be obtained from the same web address.

Analysis of Collocated TEOMs with a FRM

In New York State two sites have operating collocated TEOMs with a FRM. Additionally, a site in Raleigh North Carolina also has two TEOMs and a FRM. At each site one of the TEOMs is run with an operational temperature of 50C, while the other is operated at 30C and utilizing a Sample Equilibration System (SES). Data are compared to the operating FRM at the sites, which for all 3 locations is a R&P 2025 FRM. The site with the longest record of data is located at Pinnacle State Park in Addison, NY. This site is located in a rural area of New York's Southern Tier. The illustration below provides some indication of the improvement a TEOM operated at 30 degrees C with a SES can have over operating the conventional TEOM at 50 C. The improvement is most pronounced in the cold weather months of November through March. A table summarizing regressions for all 3 sites by month is available in attachment A.

Figure 2-16 Slope of TEOM/FRM at Pinnacle State Park, NY



Data courtesy of New York State Department of Environmental Conservation and University of Albany, Albany NY.

Conclusion

Although this analyses is very limited it's becoming clear that some areas of the country may already be operating PM continuous monitors that produce data with similar quality to that of the FRM. If a mechanism to approve the use of these continuous monitors could be made where the performance of the instrument is defined to be acceptable than a large resource savings may be gained by divesting of some of the FRM operations. Other areas of the country may not be producing PM2.5 continuous data that could be used to replace the FRM. For these areas, agencies may need to pursue improvements to their instrumentation or new technologies altogether. Comparing the performance of sites that have a collocated FRM/FRM pair with a collocated FRM/continuous pair to the expected equivalency criteria revels that the correlation statistic (R $0.97) would be the limiting factor for either FRMs or continuos monitors to meet equivalency. Section 6 of this document examines the performance standards of PM2.5 continuous monitors in detail.

Section 3. Enhanced Correlated Acceptable Continuous Methods (CAC)

Enhancements to the existing provisions for CAC monitors are being proposed in concert with a new REM program to provide agencies with options to enhance their network of PM continuous monitors. Rationale based on data comparability for selecting the CAC or REM vehicle is discussed in Sections 5 and 6. The basic premise of a revised CAC is to provide flexibility in method selection for PM monitoring sites that are not needed for direct comparison to the NAAQS and for sample frequency relief. These sites would be allowed to use CAC monitors if they meet specified performance criteria. While the current provisions for CAC(s) only allow for a reduction in sample frequency of the accompanying FRM/FEM, the provision under consideration would also allow for a continuous monitor to be approved for use without the collocation of a FRM at sites that are not required for the NAAQS. This additional flexibility is being considered for CAC monitors since agencies are not utilizing the currently defined CAC and it would be better to enhance the usefulness of CACs rather than to have another provision in the regulation. This approach would potentially be targeted for those agencies that need to monitor for a number of monitoring objectives other than NAAQS attainment decisions. Thus, while the CAC that is not collocated with an FRM cannot be used for attainment decisions, it can be used to meet all other applicable monitoring objectives, such as: public reporting, trends, mapping, and exposure. By allowing a portion of the currently required FRM sites in a network to be substituted with continuous monitors meeting performance based criteria, the monitoring agencies can realize a reduction in resource requirements while maintaining data delivery with an acceptable defined level of quality. Also, some of the remaining FRM sites would be collocated with the same continuous methods as the CAC’s to provide the performance data for ongoing assessment of the continuous method. These revised CAC’s would be different than the conventional FEM’s in that they could only replace a limited number of sites and the CAC met the performance criteria specified in Section 6 - Performance Standards for Continuous Monitoring. CAC’s would be different from REM’s in that they could not be used for direct attainment decisions unless collocated with a FRM and meeting the performance criteria identified in Section 6. Also, there would be much more flexibility in the use of data transformations as described in Section 7 - Data Transformation Policy and Guidance. This section describes the current provisions for CAC monitors and lays out the potential scope of using CAC’s in a revised network.

Performance Criteria

There are two sets of performance criteria to consider. The first set of criteria are the performance standards for acceptance of a method including individual criteria for bias, measurement precision and correlation. These criteria are provided for in section 6 with bias and measurement precision based upon the goals for measurement uncertainty as developed in the data quality objective process for the $PM_{2.5}$ monitoring program. A correlation coefficient is also included and is based on a DQO type exercise and an evaluation of the current network. Since the CAC is not used for regulatory decision making, the specific criteria for precision, bias and correlation at a site or network of sites will remain “goals” and not requirements. The second type of criteria are for on-going evaluation that the method is providing data of sufficient quality for its intended monitoring objective. These criteria are the same performance standards developed for measurement uncertainty in the $PM_{2.5}$ monitoring program and are also presented in Section 6 of this document.

Testing Requirements

There are a number of testing requirements that need to be considered. These testing requirements are intended to be designed so that State and local agencies can readily implement a field testing program to pursue a CAC for use in their network. The table below identifies the suggested criteria and rationale for CAC's:

Table 3-1 Test Specification for $PM_{2.5}$ CAC's

Testing Requirement	Suggested Criteria for CACs	Rational for Criteria
Number of Test Sites	1 on a site by site basis or minimum of 2 for a network (see Table 3-2 below)	Need to demonstrate that the method can meet performance criteria at a specific site or multiple locations in a State or local network.
Number of FRMs per site for generating baseline data in testing	1 - However strongly suggest locating test sites at collocated FRM precision sites to assure control of FRMs and to have high sample completeness	Precision of FRM can be assumed from FRM network precision statistic
Number of Candidate Samplers	Encourage 2 for first CAC site, 1 each for each additional site tested.	Need to have collocated candidate CACs in order to calculate measurement precision of the continuous method for at least one site in the network.
Number of hours to make a valid 24 hour sample for comparison to the FRM	18	75% completeness of the 24 hour period
Length of testing	All 4 seasons - however testing can begin and end at any point during the year	Need to assure that changes in aerosol or meteorology related to changes in season can meet performance requirements.
Number of data pairs - Primary Monitors, both the FRMs and the candidate CACs	90 per site with at least 20 per season See reference in section 7	Expected to be similar to 1 in 3 day sample frequency at 75% completeness for four seasons
Number of data pairs - Collocated FRMs	As found in network	Use existing collocated FRM precision sites
Number of data pairs - Collocated candidate CACs	- 60 sample pairs - At least 15 sample pairs per season	Based upon 90% confidence that the precision statistic is within 15% of the true precision. Since these are continuous methods may expect to have a substantially large data set.

Range of concentrations for siting	As found in the area of consideration.	Need to evaluate method under the conditions in which it will operate.
Range of concentrations for use in data set when determining performance of methods	May (but not required to) exclude values where the FRM concentration is below 6 ug/m^3. Exclusion of values due to low concentrations does not result in failure of completeness requirements	As concentration values approach 0, biases can appear large. By focusing on the values that are above 6 ug/m^3 estimates of the performance of the candidate methods are more stable.

Guidance for Developing Boundaries for Applicability of CAC

Section 8 of this document provides the detail for how the appropriate geographic size is determined for use of an approved CAC.

Number of test sites for Collocated Acceptable Continuous monitors

The number of test sites for CAC's depends on a number of factors such as whether one site or a network of sites is being considered for approval of a CAC and the homogeneity of the aerosol across the area of consideration. At a minimum, two sites are to be tested to support a candidate CAC across a network. The following table details how many sites are to be tested, assuming the aerosol is homogeneous across an area in which it is being tested:

Table 3-2 Test Site Specifications for $PM_{2.5}$ CAC's

Geographical Area of Consideration for CAC	**Number of Test Sites**
One MSA	2
Multiple MSA's in the same air district or State	1 for each MSA up to the first 3 MSAs, plus at least 1 site in a rural county.
Multiple States	1 for each MSA up to the first 2 MSAs, plus at least 1 site in a rural county. For each additional State add 1 urban and 1 rural site.

Note: If the aerosol is expected to vary according to the guidance provided for in section 8, then apply test sites as if each State or air district were performing testing separately. This will ensure that for each type of aerosol encountered a minimum number of sites are tested.

Review Procedures

Since the monitoring objectives for CAC's do not include direct comparison to the NAAQS, the approval procedures for use of a method should be streamlined. Thus, the review procedures should be included in the annual network review that is submitted by the State, local, or Tribal Agencies to the Region. The Region would work to determine that the performance criteria have been appropriately addressed and the continuous method is suitable for inclusion in the network. Since many agencies potentially seeking the CAC approach for relief from FRM sampling are expected to be substantially below that standard, the Regions should work towards approval of the CAC's where they make sense and not prevent their approval if a specific goal is not met. For instance, one way for Regions to make a good decision on the approval of a CAC is to utilize the DQO tool that has been developed with inputs of a number of variables and see if the uncertainty around the NAAQS would be worse or better. If the goals for measurement uncertainty are ± 10% bias and 20% CV and the agency has a bias of 5% and CV of 23% with their continuous method, then the uncertainty around the NAAQS may actually be better.

Ongoing Evaluation of Method Performance

Since the CAC is not to be used for direct comparison to the NAAQS, the specific QA/QC requirements of the $PM_{2.5}$ quality system do not apply in a strict sense. However, since the data are to be used for a number of other important monitoring objectives the $PM_{2.5}$ quality system does apply in a qualitative sense. This means that agencies must develop appropriate measures to determine precision and bias estimates for the CAC monitors used in their network, but they are not held to specific numbers as if they were regulatory monitors. Additionally, the CAC's should be appropriately addressed in the monitoring agencies Quality Assurance Project Plan (QAPP). Agencies should be evaluating the quality of their network on an ongoing basis and work to resolve problems as they are encountered.

Potential Use of CAC's in $PM_{2.5}$ Monitoring Networks

The expected outcome of having a CAC approved for use at a site or in a monitoring network is that it can be used in combination with a limited number of FRM's as part of a "hybrid" network. Section 5 of this document lays out the detailed network design of a potentially revised network.

Section 4. Regional Equivalent Monitors

A provision to allow for REM's is proposed to enhance the network of PM continuous monitors. The basic premise of a REM is that when a $PM_{2.5}$ continuous method meets the performance criteria identified in Section 6 and the testing specification described below for one or more sites in a network, then this method may be used at that single site or any sites in the network covered by the range of conditions tested. The spatial extent of the approval of the method would be based upon a number of factors such as number and location of sites tested, homogeneity of the aerosol in the network, and local contribution of the aerosol. This flexibility is being considered since some methods are expected to work well in replicating FRM measurements across specific agencies networks across all seasons, but not in every network in the country. Approved REM's would be allowed to be used for attainment decisions as part of a "hybrid" network of $PM_{2.5}$ FRM's and continuous monitors as described in section 5 - Network Design. For implementation purposes, REM's are different than the conventional FEM's in that they are only for use in a specific network or a subset of a network and a minimum ratio of FRM's must be retained across the network. Site REMs are used with model development on a site by site basis and have the potential to be implemented quickly. Network REMs are approved across a series of sites with the method, including statistically developed models, if necessary, consistently implemented. During the testing phase of a candidate REM, the FRM is identified as the *Primary* monitor, meaning it is the monitor to be used for comparison to the NAAQS at that site. If a continuous monitor is approved, this new REM now becomes the primary monitor with the FRM becoming a QA monitor. The REM's are different from CAC monitors in that data from REM's are used for direct comparison to the NAAQS, while data from CAC's are not. Since the data from REM's are used for comparison to the NAAQS, there is much more control on the approaches for data transformations, as described in Section 7. This section describes both the site and network REM as well as the test specifications and approval process.

Site REM

A provision for a site specific REM is being added so that monitoring agencies can potentially reduce sample frequency at required daily or 1 in 3 day sites to a 1 in 6 sample frequency regardless of the concentration at the site. This has the potential for an expedited implementation since the FRM data would still be available if the continuous monitor did not satisfy the performance criteria identified in section 6. If necessary, a model, as identified in section 7 would be used based upon the historical data from the site. If the correlation coefficient is satisfied between the FRM and continuous monitoring data, the sample frequency of the FRM can be reduced. The bias criteria for the historical data need not be met since the model would potentially account for the differences between the two methods. The model would be used as part of the approved continuous monitors method. The continuous monitor now becomes the approved primary monitor for the site. Each year the continuos monitoring data would be evaluated and if necessary, a new model would be developed. New models would only be used in a prospective mode. If the uncertainty of the PM2.5 continuous monitoring data is determined to be unacceptable as determined from the DQO software tool or similar approved analyses, then the continuos monitoring data is to be invalidated and the FRM data is used for comparison to the NAAQS. Since a provision already exists for "Approval of non-designated PM2.5 methods at specific individual sites"[1] (40 CFR Part 58 , Appendix C, section 2.4) the site REMs has the potential for quicker implementation than other proposals in this document.

Network REM

Network REMs can be used at any site in a network where the performance criteria as identified in section 6 are met. Network REMs can be limited to a range of sites if testing demonstrates the performance criteria are satisfied for some grouping of sites but not others. The method for a network REM is to be consistently deployed with only one transformation used, if necessary. Thirty percent of the network REM sites are to be collocated with FRMs for ongoing evaluation of the continuous monitoring data consistency with the historical record. Once the REM is approved, the FRM sample frequency can be reduced to 1 in 6. At this point the approved REM becomes the primary monitor and the FRM becomes the QA monitor.

Performance Criteria

There are two sets of performance criteria to consider. The first set of criteria are the performance standards for acceptance of a method including individual criteria for bias, measurement precision and correlation. These criteria are provided for in section 6 with bias and measurement precision based upon the goals for measurement uncertainty as developed in the data quality objective process for the $PM_{2.5}$ monitoring program. A correlation coefficient is also included and is based on a DQO type exercise and an evaluation of the current network. The second type of criteria are for on-going evaluation that the method is providing data of sufficient quality for its intended monitoring objective. These criteria are the same performance standards developed for measurement uncertainty in the $PM_{2.5}$ monitoring program and are also presented in Section 6 of this document.

Testing Requirements

There are a number of testing requirements that need to be considered. These testing requirements are intended to be designed so that State and local agencies can readily implement a field testing program to pursue a REM for use in their network. Monitoring agencies may collaborate with other parties including instrument manufacturers in the testing process; however, the agency seeking approval of a REM is responsible for overseeing the field testing as if it were part of their routine operation. This will demonstrate operation of the instruments under typical field conditions as if they were already approved. The table below identifies the required criteria and rationale for REM's:

Table 4-1 Test Specification for $PM_{2.5}$ REM's

Testing Requirement	Suggested Criteria for REMs	Rational for Criteria
Number of Test Sites	One for site REM or minimum of 2 for network REM (see Table 4-2 below)	Need to demonstrate that the method can meet performance criteria at individual site or multiple locations in a State or local agency network.
Number of FRMs per site for generating baseline data in testing	1- However strongly suggest locating test sites at collocated FRM precision sites to assure control of FRMs and to have high sample completeness	Precision of FRM can be assumed from FRM network precision statistic
Number of Candidate Samplers	1 for a site REM or 2 for first network REM test site, 1 for each additional site	Need to have collocated candidate REMs in order to calculate measurement precision of the continuous method for at least one site in the network.
Number of hours to make a valid 24 hour sample for comparison to the FRM	18 - valid hourly values within the midnight to midnight period.	75% completeness of the 24 hour period.
Length of testing	All 4 seasons - however testing can begin and end at any point during the year.	Need to assure that changes in aerosol or meteorology related to changes in season can meet performance requirements.
Number of data pairs - Primary Monitors, both the FRMs and the candidate REM	90 per site with at least 20 per season. See reference in section 7	Expected to be similar to 1 in 3 day sample frequency at 75% completeness for four seasons
Number of data pairs - Collocated FRMs	As found in network	Use existing collocated FRM precision sites
Number of data pairs - Collocated candidate REMs	- 60 sample pairs for the REM - At least 15 per season for the REM.	Based upon 90% confidence that the precision statistic is within 15% of the true precision. Since these are continuous methods may expect to have a substantially large data set.
Range of concentrations for siting	As found in the area of consideration.	Need to evaluate method under the conditions in which it will operate.

Range of concentrations for use in data set when determining performance of methods	May (but not required to) exclude values where the FRM concentration is below 6 ug/m^3. Exclusion of values due to low concentrations does not result in failure of completeness requirements	As concentration values approach 0, biases can appear large. By focusing on the values that are above 6 ug/m^3 estimates of the performance of the candidate methods are more stable.

Guidance for Developing Boundaries for Applicability of Regional Equivalent Monitors

Section 8 of this document provides the detail for how the appropriate geographic size is determined for use of an approved REM.

Number of Test Sites for Regional Equivalent Monitors

The number of test sites for REM's depends on a number of factors such as the area of consideration for approval of a REM and the homogeneity of the aerosol across the area of consideration. At a minimum, two sites are to be tested to support a candidate REM. The following table details how many sites are to be tested assuming the aerosol is homogeneous across an area in which it is being tested:

Table 4-2 Test Site Specification for $PM_{2.5}$ REM's

Example Geographical Area of Consideration for REM[8]	Number of Test Sites
Site REM	1
Network REM - One MSA	2
Network REM - Multiple MSA's in the same air district or State	1 for each MSA up to the first 3 MSAs, plus at least 1 site in a rural county.
Network REM - Multiple States	1 for each MSA up to the first 2 MSAs, plus at least 1 site in a rural county. For each additional State add 1 urban and 1 rural site.

Note: If the aerosol is expected to vary according to the guidance provided for in Section 8, then apply test sites as if each State or air district were performing testing separately. This will ensure that for each type of aerosol encountered a minimum number of sites are tested.

[8] The example presented at best reflects a minimum requirement. Definition of extent of regional applicability is addressed more completely in section 8 and is a topic requiring significant development.

Review Procedures

The approval of a “Regionally” equivalent monitor should follow the same process for review and approval of other federal equivalent methods. This process works through the Office of Research and Developments National Exposure Research Laboratory (NERL) Reference and Equivalency program. That program receives, reviews, and provides feedback to vendors and other parties that have applied for equivalency. Once all the criteria have been appropriately addressed and the candidate method has been determined to meet the appropriate performance criteria, the Reference and Equivalency program makes a recommendation that the method be approved as “equivalent.” Once approved by EPA as “equivalent,” a notice is published in the Federal Register indicating that this status has been achieved. Any geographic limitations to a methods approval would also be included in this notice.

Ongoing Evaluation of Method Performance

Since the REM is to be used for NAAQS decision making, all applicable elements of the $PM_{2.5}$ quality system are to be applied to its use. This means that REM’s are to be collocated with both FRM and the same continuous method as the primary monitor as well as being subject to performance evaluation audits defined in Appendix A of Part 58. Additionally, the CAC’s should be appropriately addressed in the monitoring agencies QAPP. If for 3 consecutive years the REM does not meet the DQO’s and a examination of the data indicates that the uncertainty in decision errors is increasing, then the monitoring agency should **- NOT SURE WHAT THE CONSEQUENCE SHOULD BE.** Would like to have agencies work through a solution.

Potential Use of Regional Equivalent Monitors in $PM_{2.5}$ Monitoring Networks

The expected outcome of having an REM approved for use in a monitoring network is that it can be used in combination with a limited number of FRM’s as part of a “hybrid” network. Section 5 of this document lays out the detailed network design of the a potentially revised network.

Section 5 - Network Design

Introduction:

The $PM_{2.5}$ monitoring program has been implemented with a heavy emphasis on FRM samplers in order to support comparing mass data to the NAAQS. Approximately 1,143 (July 11, 2001 AIRS) monitoring sites in the United States are now operational with FRM samplers. The entire $PM_{2.5}$ network includes components for chemical speciation and advanced measurements (Attachment B). Only the FRM or FEM can be used for direct comparisons to the NAAQS. This plan proposes a more balanced hybrid network of filter based and continuous mass samplers, assuming that data analysts would incorporate filter based and continuous methods (seamlessly) when utilizing network data for broad scale spatial applications such as positive matrix factorization (PMF) and air quality model evaluation. This hybrid network would include a reduced number of existing FRM samplers for direct comparison to the NAAQS and continuous samplers that meet specified performance goals related to their ability to produce sound comparisons[9] to FRM data. Two approaches described in Sections 3 and 4 for integrating continuous mass monitors are proposed to maximize flexibility for agencies; an expanded use of CAC Monitors and REM'). The CAC approach would enable agencies to address any monitoring objective, other than ***direct***[10] comparisons to NAAQS for attainment and non-attainment designations, while the REM approach would serve any objective.

There is an unknown amount of degraded data quality risk associated with moving from the current design based system to one relying on performance based specifications. Therefore, this hybrid network will maintain a core of FRM's to maintain an ability to quantify the relationship between FRM's and continuous samplers for continuity to both the historical record as well as ongoing and prospective use of continuous methods. The remaining network of FRM's might constitute 30% to 50% of the current network. A large network of continuous monitors meeting performance criteria would eventually be in place to improve the data base for: public reporting of Air Quality Indices (AQI) and mapping through AIRNow; supporting health effects and exposure studies addressing short-term exposures; evaluating air quality models and emission inventories, and supporting compliance needs related to direct comparisons with the NAAQS and delineating the spatial extent of attainment/nonattainment areas.

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[9] Comparability between FRMs and continuous samplers is desired, based on the extensive FRM network available. This practical need also recognizes inherent differences between measurement principles of integrated and continuous methods and does not assume any one type of measurement best represents true atmospheric aerosols conditions. Further discussion on incommensurabilities between measurement systems is provided in section 7.

[10] Data from CACs would be expected to be incorporated in as yet undetermined weight-of-evidence analyses to define boundaries of non-attainment/attainment areas.

Minimum Number of FRM Samplers

A separate but parallel effort is underway to better identify redundant monitoring for all pollutants as part of the National Monitoring Strategy (see Section 10). This national strategy supports an investment in continuous PM monitors balanced by a divestment in $PM_{2.5}$ FRM sampling. Progress in enhancing PM continuous monitoring requires a burden reduction in FRM sampling. Currently, nearly 1,100 FRM samplers operate across the United States, and an additional 200-300 IMPROVE and continuous samplers. The spatial richness this network should not be severely compromised; however, areas of redundancy are evident based on a variety of national and regional based assessments that illustrate broad expanse of homogeneous aerosol behavior. A reduction in required FRM samplers is possible using network assessment processes to determine effective numbers of samplers across regional and urban spatial scales. Nationally, we are suggesting that a minimum of 300-500 FRM/FEM's be retained to ensure consistency with the existing network, and provide the primary regulatory base of data. A total of approximately 600 equivalent samplers (including FRM's, FEM's and REM's) for direct comparisons to the NAAQS are recommended. The network size of approximately 600 is based on several data analyses. One analysis shows that the large spatial patterns in $PM_{2.5}$ are nearly identical whether using 300 or 1,200 monitoring locations in an area that covers much of the eastern United States. A second analysis indicates that several urban areas are likely over-sampled by approximately 25-35%. Perhaps as many as 1,000 (or more) $PM_{2.5}$ mass (FRM and continuous) sites nationally are needed for spatial characterization, but request that actual number of sites be a function State/local agency discretion as agencies must balance several competing monitoring priorities. Note, that this approach while increasing flexibility could have unintended negative consequences by accommodating too many diverse methods that do not relate well with each other. Agencies are encouraged to strive for consistency in deploying their continuous PM network and consider not only consistency of methods within an agency, but attempt to harmonize technology across regional areas.

Table 5-1 summarizes the applicability of each monitoring method category to the type of site in the network. Tables 5-2 and 5-3 include examples of revised network requirements for $PM_{2.5}$ samplers. Specific modifications to the $PM_{2.5}$ monitoring regulations are being addressed through a workgroup of State/local agency, Tribal nation, and EPA representatives (see section 11).

Table 5-1 PM Method Applicability

Method	Required Sites for NAAQS						
	< 80% of NAAQS	80% to 120% of NAAQS	>120% of NAAQS	Sites that are currently required but are not required in a future network.	Current Supplemental Sites	Background and Transport Sites	Speciation and IMPROVE
FRM/FEM	T	T	T	T	T	T	
Site REM	T • With collocated FRM operating 1-6	T • With collocated FRM operating 1-6	T • With collocated FRM operating 1-6	T	T	T	
Network REM	T • With 30% FRM collocation in network	T • With 30% FRM collocation in network	T • With 30% FRM collocation in network	T	T	T	
CAC	T • With 100% FRM Collocation in network FRM operates 1-6		T • With 100% FRM Collocation in network FRM operates 1-6	T	T	T •	
IMPROVE						T	T
Speciation						T •	T
Existing Continuous mass PM					T		

T The method category in the row is applicable for the monitoring objective in the column.

• This symbol indicates a change to the monitoring regulation is needed

Method Applicability Summary

FRM/FEM/REM - These methods can be used at a required site, regardless of the concentration; at any current or future supplemental sites; and at any background or transport sites. REM's have two categories:

1.) Site REM's have an approved continuous monitor collocated with a FRM. Once approved the continuous monitoring data is used for comparison to the NAAQS. If the uncertainty of the continuous monitoring data is outside of the goals for the PM2.5 monitoring program (utilizing the DQO software or similar approved analyses) and worse than that of the FRM, the continuous monitoring data is to be invalidated and the FRM data shall be used for comparison to the standard.

2.) Network REM's have at least 30% collocation with FRM's when they are sited at required sites. Once approved the REM would be the primary sampler when collocated with a FRM.

CAC - This monitor could provide relief up to three new ways:

To convert a site from a filter based sampler to a CAC:

1.) At current supplemental, background, and transport sites CAC monitors may be used as the primary monitor. Collocation at these sites would follow the provisions of Appendix A; which is expected to be 15% collocation with the first collocated monitor being an FRM and the next one being of the same make and model as the CAC.

2.) The minimum number of required sites is to be reduced in Appendix D of Part 58. There is an expectation that there will be more sites operating than the minimum number required. For sites that are no longer required to be operated; but the agency still intends to operate the site to meet other monitoring objectives, the agency may choose to operate the site with a CAC. Appendix A collocation requirements would apply for these CAC's. Moreover, it is feasible that revised monitoring regulations may require a similar total number of monitors currently required or operating (i.e., 850 to 1,100) with a subset required to have reference/equivalent status and the remainder being satisfied by an equivalent/reference or CAC designation.

To provide additional sample frequency relief:

3.) For required reference/equivalent sites (current or future) that are either substantially above or below the NAAQS, the CAC may be operated to provide a signal of PM provided it is collocated with a FRM operating on at least a 1-in-6 day schedule. The FRM maintains the status as the primary monitor.

The conventional sample frequency relief for a CAC would still apply:

> A FRM site that is required to operate daily may have its sample frequency reduced to 1-in-3 provided it is collocated with a CAC regardless of the concentration or NAAQS status.

Table 5-2 Network Design Criteria for $PM_{2.5}$ Required SLAMS

Network Design Criteria	Current Network	Example Revised Network
Required minimum number of sites at State and local Air Monitoring Stations (SLAMS)	Approximately 850* * 100 are for background and can use IMPROVE samplers	Assuming ~600 sites are reasonable we envision a hybrid network of FRM and continuous methods meeting acceptable performance standards. A minimum of ~ 30% of each monitoring agencies future network would be required to remain as FRMs.
Scale of representativeness - Annual Average	Neighborhood or Urban Scale with FRM or FEM	Neighborhood or Urban Scale with FRM/FEM or hybrid network of FRM and continuous monitors meeting performance based criteria
Scale of representativeness - Daily Average	Micro, Neighborhood, Urban Scale	Micro, Neighborhood, Urban Scale. For sites that are expected to only have a violation of the daily standard, but not the annual average, site with a FRM/FEM. Collocated with a Continuous monitor, if needed

Section 6 - Performance Standards for Continuous Monitoring

Introduction

The current expectations for $PM_{2.5}$ continuous monitors to receive federal equivalent monitor designation require field testing at multiple locations covering a range of environmental and aerosol conditions, over an entire year. The field data must meet conservative performance specifications that include slope, intercept, correlation and a precision test. If a candidate method meets all the criteria at each test site, then it receives an "equivalency" designation for use anywhere in the national network. The assumption is that the method will perform as intended in all areas if it meets these strict performance specifications at the test locations. Also, once a method receives an equivalency designation, no additional field tests are required to ensure that the equivalency holds through time.

The approach presented in this section attempts to link the testing requirements and the ongoing performance requirements to the Data Quality Objectives (DQOs). The DQOs identify the level of uncertainty in the data that is acceptable, given the intended use of the data. Methods that meet or are of better quality than identified in the DQOs can be used in the networks in which they were tested, provided they continue to meet the DQOs through time. The $PM_{2.5}$ Data Quality Objectives were developed for comparison of values around the 3-year annual average NAAQS since it was found to be the controlling standard (i.e. any violation of the daily standard would in almost all cases be in violation of the annual standard). However, if the daily standard is lowered it may be as influential as the annual standard in some areas. Therefore, this section will also provide information on the daily standard.

An additional DQO exercise has been performed to determine a minimum correlation coefficient for each category of continuous monitor being proposed. Since correlation was not factored into the DQO design for the PM2.5 monitoring program, it was not clear how to integrate correlation in these DQOs. The development of the correlation DQOs rely on testing whether a "true" correlation is at or below a certain value for each category of continuous monitors. Based upon the desired true correlation and accounting for error rates, an "observed" correlation can be derived that is tied to the number of sample pairs necessary.

Background and Rationale

$PM_{2.5}$ DQO Process

DQOs are qualitative and quantitative statements that clarify the monitoring objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that will be used to determine the quality and quantity of data needed to support decisions (i.e., NAAQS comparisons). A more complete description of the $PM_{2.5}$ DQOs and how they were derived is presented in Attachment B.

DQOs for $PM_{2.5}$ were developed during the months from April to July of 1997. A number of assumptions were made in order to generate realistic error rates. Table 6-1 provides a listing of these assumptions. In 2001, EPA reassessed the assumptions underlying the 1997 DQOs. In almost all cases, the assumptions made in the 1997 process held true in the 2001 evaluation.

The $PM_{2.5}$ DQOs were generated using conservative but realistic assumptions. For example, the DQOs were generated assuming a sampling frequency of every 6 days with 75% completeness. This is the lowest sampling frequency allowed in the Code of Federal Regulation. A 95% confidence limit around the annual mean at this sampling frequency would be “wider” than a 95% confidence limit for an every day sampling frequency at 90% completeness. In all cases, the assumptions in Table 6-1 are close to the extremes of realistic and allowable data. Assumptions in bold are variables that will be discussed later in this section.

Table 6-1 2001 DQO Assumptions

1. **Bias is -10% or + 10%**
2. **Precision is 10%**
3. Annual NAAQS is controlling standard
4. No spatial uncertainty and each monitor stands on its own (no spatial averaging)
5. **1 in 6 sampling with 75% completeness (144 days)** (each of 12 quarters was rounded up to 12 samples per quarter)
6. 3-year annual average is truth, (every day sampling and 100% comp.) up to bias and measurement variability
7. **Lognormal distribution for population variability, 80% CV**
8. Normal distribution for measurement uncertainty
9. **Seasonal ratio (ratio of avg conc for highest season to lowest season) = 5.3**
10. **No auto correlation in daily concentrations**
11. Bias and measurement variability (precision) applies to entire 3 years
12. **Type I and type II decision errors set to 5%**

Figure 6.1 provides the power curve based on the 2001 assumptions shown in Table 6-1. A power curve is an easy way to display the potential of decision errors based upon the choice of various assumptions that affect data uncertainty. The gray zone is the range of concentrations for which the decision errors are larger than the desired rate of 5%.

Based on the 2001 assumptions, the gray zone is 12.2 to 18.8 µg/m^3. This means that if all the 2001 assumptions hold, the decision maker has a 5% chance of observing a 3-year mean

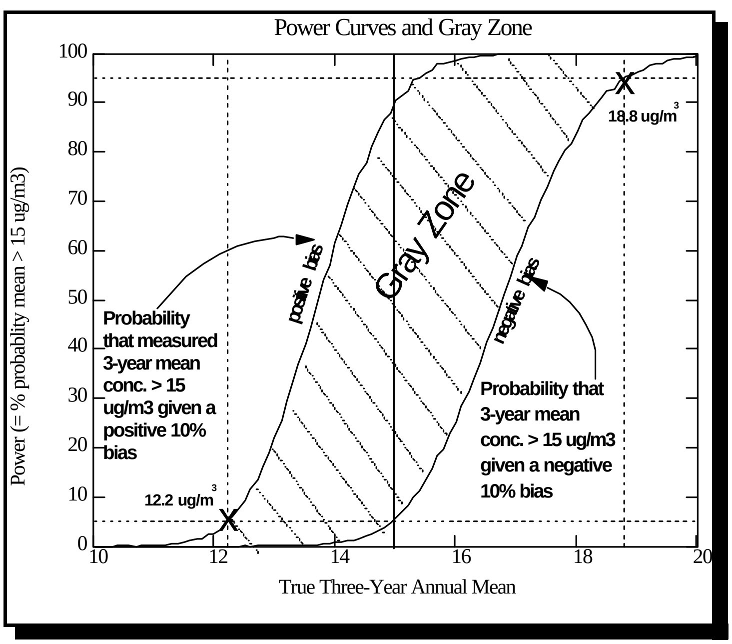

Figure 6.1 Power curve based on 2001 assumptions

concentration that is greater than 15 µg/m³ even though the true mean concentration is 12.2 µg/m³ (all assumptions and a 10% positive bias). As has been mentioned, the 2001 assumptions are realistic but conservative. For example the CY00 $PM_{2.5}$ QA Report demonstrates that the precision and bias estimates at a national level are within the DQOs. Assumptions that are "better" than those listed in Table 6-1 will tend to decrease the width of the gray zone. Figure 6.2 provides an example of the power curve/gray zone changes for a simple change in sampling frequency from 1 in 6 day (green/solid) to 1 in 3 day (blue/dots) to every day (red/dashed); all the other 2001 assumptions remain the same. Higher sampling frequencies result in narrower gray zones, meaning that decision errors are reduced. Using the same 2001 assumptions, generating a power curve for the daily standard would yield a gray zone of 32.4 to 86.0 ug/m³ (see Figure 6.3).

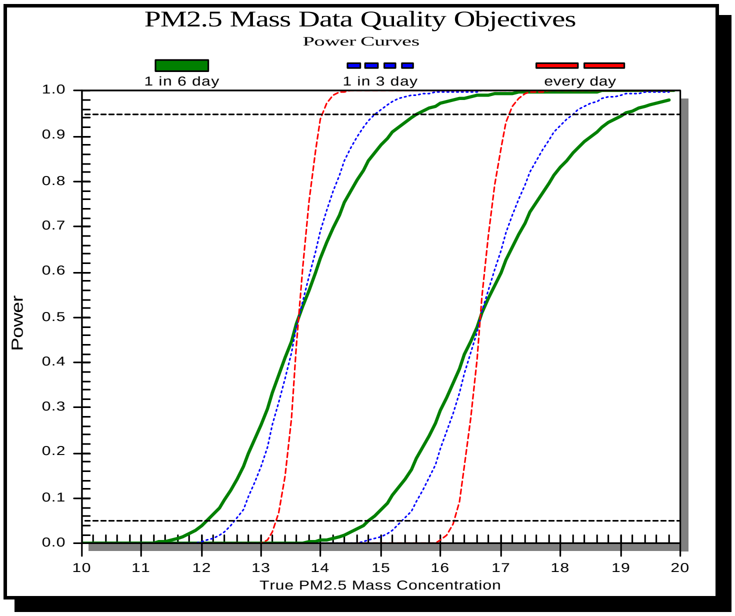

Figure 6.2. Annual standard power curve changes due to changes in sampling frequency

Because the assumptions for any particular site will vary, OAQPS commissioned the development of a software tool to help Headquarters and State, local and Tribal organizations determine the potential for decision errors based on assumptions relevant for sites within their network. The tool is based on thousands of data simulations and produces approximate gray zones. Figures 6.2 (annual standard) and 6.3 (daily standard) are generated using this tool which allows for multiple scenarios (power curves) to be reviewed on one table. The assumptions listed in bold in Table 6-1 can be changed

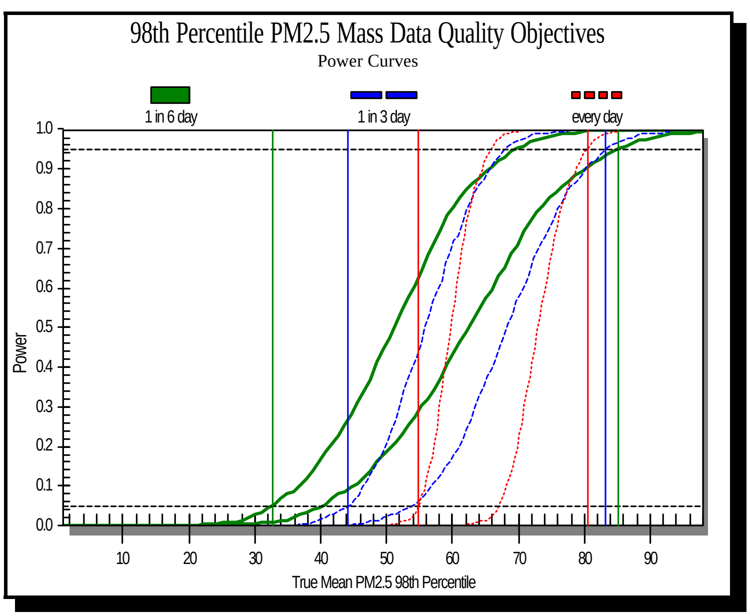

Figure 6.3 Daily standard power curve due to changes in sampling frequency

to suit a particular network. Furthermore, the tool was enhanced to include a daily air quality index (AQI) use and will be useful for making decisions about the acceptability of REMs or CACs within a network.

The $PM_{2.5}$ DQO evaluation showed that sampling frequency, population variability, completeness and measurement bias play a significant role in the width of the gray zone. Measurement precision did not have a significant effect on the gray zone for both the annual and daily standard which suggests more imprecision could be tolerated with little effect on decision errors.

Correlation Coefficient DQO Process

A DQO type exercise was performed to determine the minimum correlation coefficient necessary between data from a PM2.5 continuous monitor and a collocated FRM. The data from the PM2.5 continuous monitor is used after a transformation has been made, if necessary. The DQO exercise is based upon identification of a true underlying relationship given the intended use of the data. Other information was considered such as the current national equivalency criteria; expected sample size of collocated continuous and FRM samplers; and performance of the current network (section 2). Correlations for CAC type continuous monitors are more flexible (less strict) than REM type monitors since CAC monitors are not to be used for NAAQS decisions.

Test criteria for PM2.5 class III equivalent methods (which would include PM2.5 continuous monitors) have never been published. The current national equivalency criteria for PM10 and PM2.5 Class I and II monitors identifies a correlation of >= 0.97 based upon a minimum number of 10 sample pairs at each test site. A correlation of >= 0.97 is expected to be too difficult for most PM2.5 continuous monitors and may not even be necessary. More relaxed minimum correlation criteria can be postulated based upon two important differences between how the traditional equivalency program works and how a process for approval of REM and CAC type monitors is proposed. First, while the national equivalency program requires at least 10 valid sample pairs per site, the REM and CAC process is expected to generate many more sample pairs. This is primarily based upon the expected sample frequencies of collocated FRM samplers and a years worth of data. By having a larger number of sample pairs, more confidence in the "true" underlying correlation can be determined. Second, in the national equivalency program there is a high degree of intra-method collocation required. When the precision of the FRMs are not acceptable, that sample set is discarded. In the testing proposed in this document limited collocation is required and no provisions for invalidating a sample set is provided for based upon poor precision. This has the effect of potentially keeping FRM values that lead to a degradation of the correlation in the sample set. One of the merits of the REM and CAC process is that the testing of the instruments takes place under typical field conditions for which the monitors are to be approved. A reduction in the requirement for correlation is therefore balanced against use of a substantially larger number of sample pairs and a more "typical" FRM data set.

Identification of true underlying correlations for each category of PM2.5 continuous monitors were made. For a CAC category, a true underlying correlation less than or equal to the square root of 0.7 was chosen. For a REM a true underlying correlation less than or equal to the square root of 0.8 was chosen. These true underlying correlations are based upon an iterative process of evaluating the error rates and sample sizes needed for a reasonable observed correlation. Error rates include an alpha, beta and delta. The alpha is the chance of incorrectly concluding that the correlation between the transformed continuous and FRM data is good enough to be used when in fact the correlation is not good enough. Since one of the monitoring objectives for the REM is attainment decisions, a high alpha will be chosen to protect against using a model where the true underlying correlation is not good enough. The beta is the chance of concluding that the correlation between the transformed continuous and FRM data is not good enough when in fact it is. The problem with this type of decision is that one would work on improving the method or model relating the continuous monitor and FRM when in fact the model is already good enough. The delta is the size of the gray region.

The derivation of the data in this section is based on work documented in "Using Continuous PM2.5 Monitoring Data to Report an Air Quality Index," *J. Air & Waste Manage. Assoc.* **52**:104-112, January 2002. NOTE: In a previous application of the technique for public reporting (see Appendix C), only the tables for R <= sqrt(0.60) = 0.77 were provided. This is because the decision makers working on the DQOs for using continuous data to report the AQI decided that R <= 0.77 was sufficient. For more uses of the data, it likely is prudent to test for higher true, underlying correlations, hence 2 new sets of tables are provided below.

Another note. Sample sizes less than 20 should not be used. The reason for this is that the primary assumption behind the equations used to generate the values in the tables is that W=0.5*ln((1+R)/(1-R)) is approximately normally distributed. This assumptions appears not to be valid for sample sizes less than 20 and possibly not for sample sizes less than 30. Sample sizes less than 20 are shown but crossed off in the tables 6-2 and 6-4.

A final note. The sample sizes and R^2 in the tables have changed from those developed for the AQI DQOs. There was an error in the equations in the original derivation. That error has been corrected and the correct values are reflected in the tables below. The correction has had the effect of reducing the required number of pairs of data needed for evaluating the correlation.

Correlation for CAC category of Continuous Monitors

If the intended use of the data is for monitoring objectives other than comparison to the NAAQS a recommendation is made to test to see if the true underlying correlation is <= square root (0.7) = 0.84. For error rates a recommendation is made for a gray zone of square root (0.7) to square root (0.85) meaning delta of 0.15, alpha should be 0.05 and beta should be 0.2. This results in a **minimum sample size of 44 and a minimum correlation 0.90** (square root 0.81). This sample size represents a site operating a FRM on a 1 in 6 sample schedule at 75% completeness for a year. If more sample pairs are used then a lower observed correlation may be permissible given the same error rates.

Table 6-2. Lower Bound for Sample size requirements for model development by ", $, and) under a null hypothesis of H_0: R # sqrt(0.7) = 0.84

Size of Gray Region (Δ)	False Acceptance Decision Error (β)	False Rejection Decision Error (α)	
		0.05	**0.01**
0.20	0.3	~~16~~	25
	0.2	20	31
	0.1	27	39
0.15	0.3	34	56
	0.2	44	69
	0.1	59	88
0.10	0.3	90	152
	0.2	117	187
	0.1	160	242

Table 6-3. **Lower bound on observed model R^2 value (for above sample size) necessary for concluding model adequacy by α, β, and Δ under a null hypothesis of H_0: R ≤ sqrt(0.7) = 0.84**

Size of Gray Region (Δ)	False Acceptance Decision Error (β)	False Rejection Decision Error (α)	
		0.05	**0.01**
0.20	0.3	0.87	0.88
	0.2	0.85	0.86
	0.1	0.83	0.85
0.15	0.3	0.82	0.83
	0.2	0.81	0.82
	0.1	0.79	0.81
0.10	0.3	0.78	0.78
	0.2	0.77	0.78
	0.1	0.76	0.77

Correlation for REM category of Continuous Monitors

If the intended use of the data is for monitoring objectives to include comparison to the NAAQS a recommendation is made to test to see if the true underlying correlation is <= square root (0.8) = 0.89. For error rates a recommendation is made for a gray zone of square root (0.8) to square root (0.90) meaning delta of 0.10, alpha should be 0.01 and beta should be 0.1. This results in a **minimum sample size of 96 and a minimum correlation of 0.93** (square root 0.87). This sample size represents a site operating a FRM on a 1 in 3 sample schedule at 80% completeness for a year. If more sample pairs are used then a lower observed correlation may be permissible given the same error rates.

Table 6-4. **Lower Bound on Sample size requirements for model development by α, β, and Δ under a null hypothesis of H_0: R ≤ sqrt(0.8) = 0.89**

Size of Gray Region (Δ)	False Acceptance Decision Error (β)	False Rejection Decision Error (α)	
		0.05	**0.01**
0.20	0.3	--	--
	0.2	--	--
	0.1	--	--
0.15	0.3	~~12~~	~~19~~
	0.2	~~15~~	22
	0.1	~~19~~	28
0.10	0.3	37	61
	0.2	48	75
	0.1	64	96

Table 6-5. Lower bound on observed model R^2 value (for above sample size) necessary for concluding model adequacy by α, β, and Δ under a null hypothesis of H_0: R ≤ sqrt(0.8) = 0.89

Size of Gray Region (Δ)	False Acceptance Decision Error (β)	False Rejection Decision Error (α)	
		0.05	**0.01**
0.20	0.3	--	--
	0.2	--	--
	0.1	--	--
0.15	0.3	0.93	0.93
	0.2	0.92	0.93
	0.1	0.91	0.92
0.10	0.3	0.88	0.89
	0.2	0.87	0.88
	0.1	0.86	0.87

CONCLUSIONS FROM DQO TOOL

The $PM_{2.5}$ mass DQOs were developed for making decisions about the 3-year average of annual means, since the annual standard is the controlling standard. In particular, they were developed to evaluate the chance of concluding an average concentration was above 15 µg/m^3, when in truth it was not, and the chance of concluding an average concentration was below 15 µg/m^3, when in truth it was not. Due to the minimum number of measurements that go into the 3-year average of annual means (at least 144), it is easy to see why measurement precision does not have a large influence on the size of the gray zone of the power curve. However, data uses that involve no averaging, such as real-time reporting like the AQI, are more sensitive to measurement imprecision. Thus, caution should be exercised in drawing conclusions from the DQO power-curve tool for uses other than those for which it is currently designed. If the assumptions are not appropriate or if the data use is different than comparison to the standards, the power curves and gray zones likely do not reflect the true decision errors. However, the tool is extremely useful in showing the effects of various types of population and measurement uncertainties on decision errors.

The software tool is available on the AMTIC $PM_{2.5}$ Website. In addition, we hope to be able to develop a report in AIRS that would automatically generate the DQO assumptions listed in Table 6-1 by a variety of data aggregation schemes (i.e., reporting organization, by a collection of sites etc.)

Acceptable Performance Criteria for Continuous Monitoring Using Power Curve Tool

Figure 6.1 set up the most extreme case that is tolerated in the $PM_{2.5}$ DQO, based on the assumptions in Table 6-1. The DQOs have associated with them a gray zone which will be used to develop acceptable bounds for the quality of the data required (REM) or recommended (CAC) for the continuous monitoring program. An important note is that the data for which the quality is being evaluated is not the raw data produced by the continuous monitors. Rather it is the continuous data that has been transformed, using a statistical model, to be FRM like. A description of the transformations and applicability to REM and CAC is described in section 7.

Table 6-6 summarize the assumptions for a REM and CAC, as it pertains to data use, allowable transformations, and data quality requirements or goals.

Table 6-6 Summary of assumptions for REM and CAC

REM	CAC
Assumptions: Will be used in comparison to NAAQS Must have FRMs in Network Can include transformations with one or more variables so long as each variable can be controlled Must meet 1-3 day DQO (gray zone) but specifically meet 10% bias DQO and correlation coefficient of 0.93.	***Assumptions:*** Will not be used in comparison to NAAQS Must have FRMs in Network Can include complex transformations Should meet **1-6 day** DQO (gray zone) but specifically meet 10% bias DQO and correlation coefficient of 0.9

Developing performance criteria using the power curve tool is a multi-step process. The first step is to collect information from the CAC/REM network. The second step is to develop a transformation that produces FRM-like data from the CAC/REM (details of which are provided in Section 7). The third step is to determine the spatial extent for which the transformation is appropriate (details of which are provided in Section 9). The fourth step is to determine reasonable values for the highlighted parameters in Table 6-1. The values should be reflective of the entire spatial extent of the CAC or REM network being evaluated. The last step is to use the DQO software tool to determine the gray zone that results from the values from the previous step. If the bias is within -10% and +10%, the gray zone is within 12.7 and 18.1 $\mu g/m^3$ (the gray zone for an FRM that operates every third day) and the correlation between collocated FRMs and continuous monitors is at least 0.93 and is based on at least 96 pairs, then the continuous sampler meets the requirements for being a REM. If the bias is within -10% and +10%, the gray zone is within 12.2 and 18.8 : g/m^3 (the gray zone for an FRM that operates every sixth day), and the correlation between collocated FRMs and continuous monitors is at least 0.90 and is based on at least 44 pairs then the continuous sampler meets the goals for being a CAC.

Figure 6.4 provides an example of the power curve for a 3-year mean based on the following data quality input parameters:

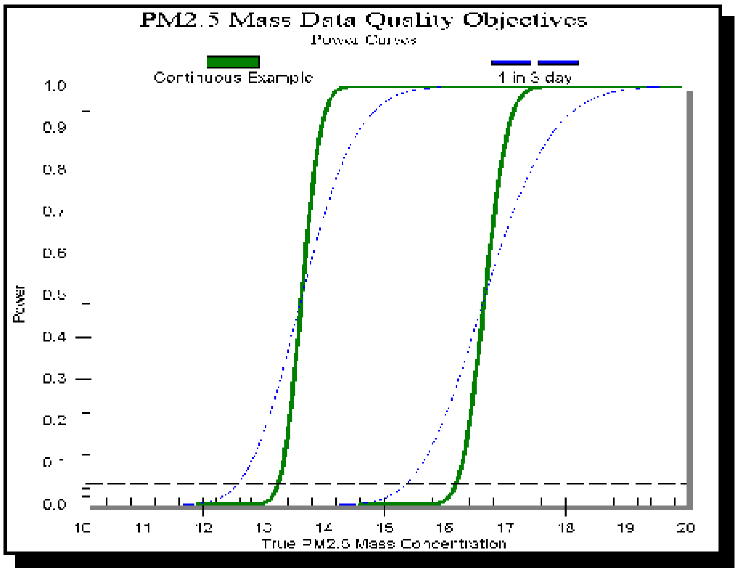

Figure 6.4. Example continuous monitoring network power curve relative to 1 in 3 day power curve.

<	bias	10%
<	completeness	75%
<	sampling frequency	every day
<	measurement CV	30%
<	population CV	80%
<	Seasonal ratio	5.3

The resultant gray zone is 13.2 µg/m^3 (lower left line green solid) and 17.1 µg/m^3 (upper right line green solid which is within the 1-3 day DQO of 12.7 (lower left blue dashed) and 18.1 (upper right blue dashed). Therefore, this example continuous monitoring network could be considered acceptable for CAC or REM designation.

Simplified Performance Criteria for Continuous Monitoring

Organizations may use the DQO process described above to determine levels of measurement imprecision that can be tolerated but still provide data of a quality to support decisions about comparison to the NAAQS. For organizations not interested in using the DQO tool to develop gray zones applicable to specific areas, the DQOs are set to 20% measurement CV, bias within -10% and +10%, and correlation greater than 0.93 for REM and 0.90 for CAC. REMs are required to meet these objectives whereas it is highly recommended that CACs meet these objectives.

Summary of Performance Criteria for $PM_{2.5}$ Methods

When discussing performance criteria, it's important to clarify the difference between acceptance of a method in the designation process and the on-going performance based goals. The acceptance of a method in the designation process is associated with the Reference and Equivalency program defined in 40 CFR Part 53. This process is purposely strict in order to assure the quality of data when subsequently designated methods are used throughout the country. Table 6-7 summarizes each category of existing and potentially revised methods with criteria for acceptance of the method and criteria for the on-going evaluation of the performance of that method.

Table 6-7. Performance Specifications for PM2.5 Methods

Category of Method	Requirements for Acceptance of Method	Existing Performance Goal for Acceptable Measurement Uncertainty	Future Performance Goal for Acceptable Measurement Uncertainty
FRM	Many design and performance criteria. Precision for field testing: < 2 $\mu g/m^3$ when concentration is <40 $\mu g/m^3$ (24 hour sample) or <30 $\mu g/m^3$ (48 hour sample); Rpj <5% for concentration > 40 $\mu g/m^3$ (24 hour sample) or >30 $\mu g/m^3$ (48 hour sample).	10% coefficient of variation (CV) for total precision and +/- 10 percent for total bias.	No Revision
FEM	Across a limited number of field test sites depending on class of equivalency: Slope of 1+/- 0.05 Intercept of 0 +/- 1 µg R $ 0.97	10% coefficient of variation (CV) for total precision and +/- 10 percent for total bias.	No Revision.
REM	Within each network that is being considered: 20 % coefficient of variation (CV) for total precision and +/- 10 percent for total bias and correlation coefficient of $ 0.93.	NA	Utilize 1 in 3 day DQO/Powercurve or simplified approach of 20% coefficient of variation (CV) for total precision and +/- 10 percent for total bias and correlation coefficient of $ 0.93.
CAC	Within each network that is being considered: 20 % coefficient of variation (CV) for total precision and +/- 10 percent for total bias and correlation coefficient of 0.9 (Goal, not requirement.)	NA	Utilize 1 in 6 day DQO/powercurve or simplified 20% coefficient of variation (CV) for total precision and +/- 10 percent for total bias. (Goal, not requirement.) And correlation coefficient of $ 0.90

Section 7. Data Transformation Policy and Guidance

Variations in $PM_{2.5}$ measurements attributed to methodological differences should be minimized to support consistent data analysis across temporal and spatial regimes. For example, it would be erroneous to infer that 20% of the $PM_{2.5}$ measured in an urban area is due to local sources based on a comparison of the concentrations measured by monitors in an urban area to concentrations from upwind sites, if the instrumentation at the upwind sites are biased low by 20%, relative to the instrumentation used in the urban area. Realistically, $PM_{2.5}$ measurements should "look" like measurements taken by an FRM. This is because of the richness of the available FRM data base and due to the difficulty in ascribing a "reference" check for aerosol measurements.

Non-FRM samplers generally operate at a higher temporal resolution than FRMs and many will operate where there is no FRM, thus helping to fill spatial gaps in the FRM network. However, to be able to use data from multiple types of $PM_{2.5}$ mass monitoring networks (FRM, non-FRM) in the same analysis, the data must be comparable. Comparable means that if the various samplers were spatially and temporally interchanged, approximately the same concentrations would be measured. To achieve comparability, it is possible to transform, using statistical models, non-FRM data to look like FRM data or vice versa. Due to the interest in FRM-like concentration surfaces, the remainder of this section will only address transforming data from non-FRM samplers to produce FRM-like measurements.

Due to the inherent differences in measurement principles between FRM and PM continuous monitors there may be biases between the measurements obtained from an FRM and continuous monitor. If the bias is consistent through time and across space, a standardized correction factor could be used to produce FRM-like measurements from the continuous monitors. However, since mass concentration and composition and environmental conditions vary, a standard correction may not be practical on a national scale but may be achievable on a more regional scale. This section provides information about the development of transformations to produce FRM-like measurements from continuous measurements.

Based on preliminary analyses summarized in Section 2, developing a statistical model to relate concentrations from continuous samplers (predominantly TEOM's) to FRM samplers is achievable, although the complexity of the model varies by location and may vary through time. The complexity likely is a function of the stability of the composition of the aerosol, the stability of the meteorology (temperature and humidity), and the continuous monitoring methodology. The following guidance for developing transformations is based on the experience gained in analyzing the limited collocated FRM/continuous database to date. The database is limited due to temporal representativeness (at best 2 years since the FRM network was deployed in 1999), spatial representativeness (continuous samplers have been and continue to be deployed predominantly in large urban areas), and non-FRM sampling techniques. The database is predominantly based on data reported to AIRS. Prior to 2000, it was not possible to determine whether the data from a continuous monitor was reported after being adjusted by "correction" factors. Beginning in 2000, AIRS method codes were expanded so that it would be possible to determine whether correction factors had been applied, although it is not possible to specify the form or parameter estimates of the adjustment. These new method codes appear not to be accurate for all sites, as seen in Section 2, making it a further challenge to determine appropriate transformations.

A balance between forcing a particular measurement principle to mimic another (i.e., the FRM) is a significant complication that must be recognized in this task. The practical needs for data analysts demand some level of comparability. However, there is intrinsic value in the very differences that emerge between measurement systems due to the complex character of aerosols. The intention clearly is not to define the FRM as truth, but rather to recognize the practicality of the existing network. These considerations of basic measurement principles are embodied in this transformation guidance. Where relationships between two measurement systems exhibit simple linear and constant character, one can probably assume the difference in measurement approach does not result in a significantly different indicator of ambient aerosol.   Such simple relationships are the foundation for accommodating REMs that can be compared to the NAAQS. Variables that can be controlled such as ambient temperature are also permissible in a multi-variate REM model. On the other hand, more complex relationships between a candidate system and the FRM suggest that a significantly different aerosol property is being accounted for (likely varies over time or space) in one system relative to the other. This does not mean one system is superior to the other, but reasonable judgement suggests a limit to forcing a system to mimic the FRM for regulatory use, but to accommodate the system for other data uses within the limits of data comparability guidelines.   This latter approach reflects the concept underlying the expanded use of CAC's.

The guidance on transformations will be broken into two sections, one for the CAC and one for the REM. The guidance for acceptable transformations for REM's will be strict and limited to transformation models where each variable can be controlled. Acceptable transformations for CAC's will be less strict. For either case, recall that the performance criteria presented in Section 6 is based on the transformed continuous measurements. Note that if the performance criteria are met with the raw continuous measurements, then no transformation is required. That is, transformations need not always be developed.

Regardless of whether the continuous sampler is a CAC or REM, measurements should be reported to AIRS. Given that data users might not understand the differences in the sampling methodologies, it is recommended that the data be entered AFTER applying a transformation to produce FRM-like measurements. However, it will be important for other data uses to know what transformations have been applied. EPA will be investigating possible ways to include the transformation information in AIRS so that it will be possible to "back out" the transformation and have the original, non-FRM measurements.

Transformation Guidance for CAC

Even though the data from a CAC will not be used for direct comparison to the NAAQS, they should meet the performance criteria as described in Section 6. Although this is not a requirement, it is strongly recommended for comparability of measurements across the network. The data used for evaluation in the DQO process are those that have been transformed to be FRM-like; that is, the DQO's are not necessarily based on the raw data from the non-FRM's. This section describes the process for developing the transformations for CAC's. The rationale and details for the selection of many of these criteria are included in the EPA document *Reporting an Air Quality Index (AQI) Using Continuous $PM_{2.5}$ Data: Data Quality Objectives (DQOs) and Model Development for Relating Federal Reference Method (FRM) and Continuous $PM_{2.5}$ Measurements (Attachment C)*.

Step 1. Create daily non-FRM measurements. If the non-FRM data are collected more frequently than daily, the sub-daily intervals should be averaged before comparing to the FRM data. At least 75% of the sub-daily intervals should be valid to consider the average to be valid. Also, the sub-daily intervals to be averaged should be those that most closely span midnight to midnight, the operating interval of the FRM's.

Step 2. Determine if there are sufficient data to develop statistical model. The model to relate the non-FRM and FRM data should be based on data from all four seasons and have at least 44 valid pairs of data, approximately evenly distributed through each season. It is recommended that each season have at least 11 valid pairs. If there are not more than 44 valid pairs approximately evenly distributed through the seasons, it is recommended that additional data be collected. The 44 pairs need not be from only one year.

3. Develop a statistical model. The statistical model relating the non-FRM and FRM data should have the FRM data as the response variable (also called the dependent variable) and minimally must include the non-FRM measurements from *Step 1* as an explanatory (independent variable). The number and type of explanatory variable allowed in unlimited. The model can be based on the data as is or can be based on the natural logarithms of the data. The final R^2 between the measured and predicted FRM measurements should be 0.81 or greater (corresponding to a correlation of 0.90 or better).

4. Spatial extent for use of one transformation. Section 8 describes the process for determining the area within which one transformation may be used for all of the continuous samplers, regardless of whether the continuous sampler has been previously collocated with an FRM.

5. On-going evaluation of transformation and its spatial extent. The statistical model should be revisited every 3 years, or more frequently if there is reason to believe a change in the relationship between the non-FRM and FRM may have occurred. Possible reasons for such changes include, but are not limited to, a change in sampling methodology, change in aerosol composition due to control strategies, or different meteorological regimes than what was observed during the development of the statistical model. If a new statistical model is more appropriate, that model should be used from that date forward. That is, one model would be used up to one date and the next model would be used for subsequent dates.

Transformation Guidance for REM

The data from REM's must meet the performance criteria as described in Section 6. The data used for evaluation in the DQO process are those that have been transformed to be FRM-like; that is, the DQO's are not necessarily based on the raw data from the non-FRM's. This section describes the requirements for the transformations. Because the data are intended to be used for NAAQS comparisons, the allowable statistical models and parameter estimation will be explicitly defined. The guidance components are as follows.

Step 1. Create daily non-FRM measurements. If the non-FRM data are collected more frequently than daily, the sub-daily intervals should be averaged before comparing to the FRM data. At least 75% of the sub-daily intervals should be valid to consider the average to be valid. Also, the sub-daily intervals to be averaged should be those that most closely span midnight to midnight, the operating interval of the FRM's.

Step 2. Determine if there are sufficient data to develop statistical model. The model to relate the non-FRM and FRM data should be based on data from all four seasons and have at least 91 valid pairs of data, approximately evenly distributed through each season. It is recommended that each season have at least 20 valid pairs. If there are not more than 90 valid pairs approximately evenly distributed through the seasons, it is recommended that additional data be collected. The 91 pairs need not be from only one year.

Step 3. Develop a statistical model. The statistical model relating the non-FRM and FRM data should have the FRM data as the response variable (also called the dependent variable) and minimally must include the non-FRM measurements from *Step 1* as an explanatory (independent variable). One or more additional explanatory variables are allowed so long as the variable(s) can be controlled. Examples of additional exploratory variables that can be controlled include ambient temperature and barometric pressure as these variables are used for active flow control on most monitors. Variables such as Julian date or using multiple models above and below a specific temperature or concentration are also permissible. The model can be based on the data as is or can be based on the natural logarithms of the data. The final R^2 between the measured and predicted FRM measurements should be 0.87 or greater (corresponding to a correlation of 0.93 or better).

Step 4. Spatial extent for use of one transformation. Section 8 describes the process for determining the area within which one transformation may be used for all of the continuous samplers, regardless of whether the continuous sampler has been previously collocated with an FRM.

Step 5. On-going evaluation of statistical model and its spatial extent. At least 30% (rounding up) of the non-FRM sites must be permanently collocated with FRMs to provide the data needed to evaluate regularly the reasonableness and consistency of the transforms. The collocated sites should be distributed to represent different composition and meteorological regimes. The statistical model should be revisited every 3 years, or more frequently if there is reason to believe a change in the relationship between the non-FRM and FRM may have occurred. Possible reasons for such changes include, but are not limited to, a change in sampling methodology, change in aerosol composition due to control strategies, or different meteorological regimes than what was observed during the development of the statistical model. If a new statistical model is more appropriate, that model should be used from that date forward. That is, one model would be used up to one date and the next model would be used for subsequent dates.

Section 8. Defining Regional Applicability

The basic relationship between a continuous monitor and an FRM should be similar throughout a given "region" of application, especially with respect to bias. This reasoning is the foundation for the new regional equivalent method approach which assumes consistent monitor behavior can be achieved within a "region" despite inconsistencies nationally. Sections 3 and 4 provided example requirements (minimum 2 sites per MSA) for demonstrating consistency. The determination of regional applicability should be based first on technical considerations related to the consistent performance of a candidate continuous method. This section addresses approaches to determine regional applicability, and is intended to raise the understanding of this topic for further development of applications guidance.

Operationally, only one transformation model would be applied within the region of consideration. Determining the region in which the use of one transform is appropriate, meaning that all the sites within the region will meet the bias, precision and correlation requirements (REM) or goals (CAC), can be approached in two ways. One approach is to establish regions a priori where the regions explicitly cover specific land masses in the United States. For example, regions may be the interior southeast, the east coast, Florida, the industrial belt, the Midwest, the western coast, the arid Southwest, Alaska, the Rocky Mountain States, and the humid northwest coastal area. The testing requirements for a candidate method would have to be met throughout one or more of these previously established regions. If one of the sites does not meet the testing requirements, then the method can not be used within that region. Such an approach implies knowledge about areas in which a particular type of continuous methodology and the FRM's have similar relationships. As shown in Section 2, knowledge based on the analysis of ambient measurements does not currently exist due to lack of data, especially data from emerging continuous monitoring methodologies. However, as more ambient measurements are collected for the various continuous monitoring methodologies, environmental conditions, and particulate composition and size distributions, such regions may become more clearly defined. EPA and other organizations (monitoring agencies, Tribal nations, Regional Planning Organizations [RPO's]) would address logistical and administrative complications associated with multiple monitoring organizations operating in a defined "region."

A second approach is to allow any size and shape of region. The State/local/Tribe, RPO, or vendor interested in using a particular type of continuous instrument would specify the boundary of the region and then follow the testing requirements or goals to prove whether one transformation would be adequate for the entire region. This may follow established geo-political boundaries such as a State including all local monitoring agencies or multiple cooperating states. The domain of the region is flexible. However, once the testing has been completed for a specific domain, the domain remains fixed until on-going evaluations indicate the performance criteria are no longer being met throughout the region or additional testing supports extending the region of approval.

It will be strongly encouraged that potential continuous monitoring methodologies be deployed at a core set of sites where the data from these sites will help to determine potential regions for the first approach. Until there are sufficient data to determine appropriate regions, the second approach will be used.

Definition of Regionality of Transformation

For a specific type of continuous monitoring methodology, given a sufficiently dense monitoring network of these monitors collocated with FRM's, it would be possible to develop a surface of the bias between the two types of instruments. In some places, the bias might be small while in other places the bias might be large. In some places, the bias might be negative and in others, it might be positive. Hopefully, the surface of biases would be smooth, that is, it would gradually change from one location to the next. Given such a smooth surface, it would be possible to produce FRM-like measurements at any location, even if there were no collocated FRM.

A difficulty with this construct of a surface of biases is that there is not a sufficiently dense network with which to build a surface for any large geographical area, especially for each type of continuous monitoring methodology. However, understanding this surface is the basis for being able to know sizes of regions. Collection of data with which to build such a surface is an important step to understanding regionality and is described below.

A surface of biases implies that the transformation to generate FRM-like measurements from continuous data would vary from site to site. Implementing site-specific transformations likely would prove to be intractable for a large number of sites, especially if the transformation is considered to be part of the method. One way around this problem is to use one transformation over an area where the biases are "similar." Specifically, the definition of the regionality of a transformation is that geographical area in which it is possible to use one statistical model to estimate FRM-like measurements and those FRM-like measurements meet the performance criteria specified in Section 6. This may possible in a modified geographical approval for a method where small cities and rural areas are approved for a method but larger cities are not. This might be necessary when small cities and rural areas encounter a relatively stable aerosol leading to little bias on a continuous instrument while larger cities encounter a higher fraction of unstable aerosols leading to unacceptable levels of bias on a continuous instrument. Determining regions for which biases are "similar" also hinges on a dense data base of collocated FRM's and continuous instruments.

Data Collection to Support Definition of Regionality of Transformations

At least 100 sites of collocated continuous monitors and FRM's will be established as part of a National Core (NCore) network. These collocated sites will provide the data necessary to understand and monitor the temporal and spatial relationships between FRM's and continuous samplers. Characteristics of the sites include: (1) FRM's should operate at least every third day; (2) monitors should operate year-round and every year; (3) speciation trends sites are ideal given that the speciated data may help better understand the relationships; and (4) sites upwind of the speciation trends sites are also ideal, as the upwind sites likely have different compositions due to urban/rural gradients. The database generated by these sites will be regularly analyzed to determine if and how the FRM-continuous relationships vary spatially and temporally and how those relationships may change over time as compositions change due to implemented control strategies.

Until such time that a priori regions are defined, the regions may be any size and shape and the following guidance is applicable.

Regionality of Transformations for CAC

If the data from the non-FRM's are intended to be used for nonregulatory purposes, it is important that the data be comparable to the data produced by FRM's. However, since the data will not be used for direct comparison to the NAAQS, there is more flexibility in determining the regions within which one transformation is applicable.

Step 1. Develop transformations for each collocated site within the region of interest, based on the guidance provided in Section 7.

Step 2. Determine whether the transformations are statistically equivalent. For the sites that are equivalent, pool their data together to estimate one transformation. This one relationship should be used at each of the sites that was considered equivalent and may be used at other continuous sites for which there is no collocated FRM, provided that the sites operate the same type of non-FRM sampler using the same standard operating procedures, have similar chemical composition, and are exposed to similar meteorology. For examples, it would be inappropriate to apply a relationship established at a site running a TEOM to a site running a BAM, to apply a relationship established at a population-oriented site without any nearby sources to a site impacted by a large local source, or to apply a relationship established at an inland site to a coastal site. Sites that are not statistically equivalent to others should be considered unique, meaning that the transformation for the site should not be applied to any other site.

Step 3. On-going evaluation. It is recommended that at least 10% of the non-FRM sites be collocated with FRM's for at least 1 year of every 3 years and that the regionality be re-evaluated every 3 years. This recommended level of collocation on a permanent basis generally is met or exceeded in current networks.

Regionality of Transformations for REM

Following the approaches for CAC and REM discussed in Section 4, the approval process for regional applicability for REM's would be considered part of the method. The method approval process would follow the same process for review and approval as other candidate federal equivalent methods.

Section 9. Monitoring Methods Guidance and Support

Despite a substantial allocation of resources in overall PM monitoring implementation, very little methods development work has been performed in the area of $PM_{2.5}$ continuous monitors. This lack of development combined with requirements for lengthy field testing in multiple sites and high statistical correlations for designation as a $PM_{2.5}$ Federal Equivalent Method (FEM) have resulted in no applications for designation of continuous $PM_{2.5}$ monitors as FEM.

Introduction:

During the planning stages of the $PM_{2.5}$ monitoring program there was little emphasis on development of PM continuous methods by EPA. There were no nationally coordinated field testing programs to assess the usefulness of continuous methods over a variety of locations and aerosols. A guidance Document was written in 1998 compiling the available field testing on PM continuous methods to date; however, this document offered little insight on planning a long term strategy of using $PM_{2.5}$ continuous methods for regulatory purposes. Additionally, EPA never actually proposed or promulgated Class III equivalency criteria that would provide the testing requirements for $PM_{2.5}$ continuous methods. Since no criteria have ever been proposed there has never been an opportunity for the various stakeholders in the monitoring community to provide comments on the usefulness of the Class III equivalency testing criteria. There is an expectation that the equivalency criteria for Class III designations would be at least as strict as the Class II criteria. But since these criteria have never been published by EPA there is no clear path for acceptance of $PM_{2.5}$ continuous methods. Without EPA directly involved in developing PM continuous methods, vendors have been left to pursue improvements on their own. While some vendors have been successful at improving their methods by working directly with the States, these methods have not been appropriately tested on a national scale. For instance, the California Air Resources Board (CARB) has been working with the Met One Beta Attenuation Monitor over the last few years, yet very little data exists on this method collocated with FRM's in any east coast States. Also, Rupprecht & Patashnick Company have commercialized the SES as an add on to the TEOM PM continuous monitor to allow for operation of this instrument at lower temperatures; however, little information is known about the long-term usefulness of the SES. The result of all of this is that there are no designated equivalent methods for $PM_{2.5}$ continuous monitors. Also, little information is available in the form of peer reviewed field studies over a variety of methods and locations. Despite all these issues there is still a great deal of information to glean from monitoring agencies and vendors on how these methods may be best suited for implementation in routine regulatory networks. This section attempts to summarize a number of points in how to best set-up and operate $PM_{2.5}$ continuous monitors. Many of these suggestions have already been incorporated into commercially available monitors. None of the suggestions should be considered as "required" since ultimately the best measures of success are performance of the $PM_{2.5}$ continuous monitor with respect to its ability to reproduce itself (measurement precision) and comparison to a FRM (bias).

Recommendations for Design and Operation of $PM_{2.5}$ Continuous Methods

In order to design an appropriate configuration for a $PM_{2.5}$ continuous monitor, many issues need to be addressed. This section attempts to provide the general specifications for $PM_{2.5}$ continuous methods. A detailed accounting comparing the FRM design and performance specifications with applicability to a generic $PM_{2.5}$ continuous monitor follows.

Comparing FRM and Continuous Methods for Design and Performance Criteria

The FRM is based upon both design and performance criteria as identified in 40 CFR, Part 50, Appendix L. Design criteria are applicable to components of the reference method such as the inlet and second stage separation device. Performance criteria are applicable to things such as the control of flow rate and maximum allowable temperature difference between the filter and the ambient temperature. For any potential continuous method to be used in the routine regulatory network only performance criteria with respect to the comparison of collocated FRM and continuous data are to be used. However, the performance of a continuous method may be expected to be optimized by adhering to as much of the reference method as practical. In reality, many aspects of the design and performance of the FRM will not be included in a continuous methods operation due to the measurement principle of the instrument or other factors. For instance, much of the laboratory FRM criteria are not practical since there is not expected to be any pre or post-sampling gravimetric analyses in the traditional sense. This section discusses the current understanding of the FRM design and performance criteria that may be applicable to a potential continuous method for use in a regulatory network. Also, where applicable, alternatives to the design and performance criteria of the FRM are included as may be appropriate for use with continuous methods. This section is intended to provide information on how a continuous method might best be designed so that resulting data mimic that of the FRM. Due to the inherent operation of any one continuous method, many of the FRM design and performance criteria may not be suitable for inclusion in its design; therefore, none of the FRM criteria are required. Also, improvements to a design or performance criteria of the FRM are encouraged where appropriate in order for resulting PM continuous data to match that of the FRM.

General Specifications

There are many specifications listed in the FRM as detailed in 40 CFR, Part 50, Appendix L. Among the general specifications, a number of items may be applicable to PM continuous monitoring. This section details those general provisions of the FRM that should be included in the design of a PM continuous method:

- *Pollutant* - Fine particulate matter having an aerodynamic diameter less than or equal to a nominal 2.5 micrometers in the ambient air. Surrogates of this are possible if they result in meeting the necessary performance standards identified in section 6 of this document.

- *Units* - Provide for data to be reported in units of micrograms per cubic meter. This may be calculated directly or indirectly through use of other inputs.

- *$PM_{2.5}$ measurement range* - Provide for a lower and upper concentration limits that allow for meaningful comparison to the FRM. While the FRM is estimated to have a lower concentration limit of at least 2 ug/m^3 and upper concentration limit of at least 200 ug/m^3, continuous methods may be able to operate over an even wider range of concentrations. Most importantly, PM continuous methods need to provide concentration values in the environments they operate in. For instance, in an extremely dirty environment, a continuous method may be able to operate above 200ug/m^3, if designed appropriately. Similarly, when a continuous method is operated at a very clean site the performance of the instrument should be able to discern changes in ambient $PM_{2.5}$ even over very low concentrations.

- *Sample Period* - Provide for a sample period that can be used to calculate the midnight to midnight 24-hour average $PM_{2.5}$ concentration. For all other criteria pollutant continuous data the reported averaging period is usually 1-hour. Depending on the measurement precision of the PM continuous instrument an averaging period of more than one hour may be necessary. Therefore, while 1-hour averages should be capable of being reported; longer averaging periods may be necessary depending on the measurement precision of the instrument.

- *Accuracy and Precision* - Because of the size and volatility of the particles making up ambient PM vary over a wide range and the mass concentration of particles varies with particle size it is difficult to define the accuracy of $PM_{2.5}$ measurements in an absolute sense. The accuracy of $PM_{2.5}$ measurements is therefore defined in a relative sense, referenced to measurements provide by the FRM. Section 6 defines the performance standards for $PM_{2.5}$ continuous methods.

Design Criteria

Design criteria for the FRM are largely associated with the inlet and separation device to obtain the desired size selection of aerosol in the sample stream. Many of these criteria can be applied to a potential continuous method. Most of the commercial vendors of PM continuous methods have already incorporated these design criteria into their instruments. The table below describes the various design criteria for the FRM and their applicability to PM continuous methods. Also, where appropriate, alternatives to the FRM design criteria are offered:

Design Areas	Section of Appendix L	FRM specification	Applicability to Continuous Methods

Inlet Assembly	7.3.2	PM_{10} head with dimensions as described in figures L-2 through L-18. Use of louvers is recommended, but not required.	This should be applicable to most PM continuous methods
Downtube	7.3.3	With dimensions as described in figure L-19	This may or may not be applicable to a PM continuous method. A downtube may not be needed if there is sufficient clearance for the PM 10 head above the monitor. Also, there needs to be a provision for a leak check adapter to be attached at the point where the PM_{10} heads attaches if the downtube is not utilized.
Impactor	7.3.4	WINS with dimensions as described in Figures L-20 through L-24.	The WINS may be used or alternatively the Very Sharp Cut Cyclone (VSCC) or other cyclone providing an appropriate $PM_{2.5}$ separation may be used. The VSCC is expected to maintain an appropriate separation of coarse and fine particulate over a longer period of time than the WINS making it more suitable for use with $PM_{2.5}$ continuous monitors.
Filter Holder Assembly	7.3.5	Many specifications as described in the text and with dimensions as detailed in Figures L-25 through L-29.	Most of the filter holder assembly design specifications will not be applicable to PM continuous monitors. Some of the important areas to strive for in the design of a PM continuous method include: - providing for a uniform face velocity of the sample stream during sample collection. - preclude significant exposure of the filter (or surrogate collection device) to possible contamination.
Flow Rate Measurement Adapter	7.3.6	As described with the dimensions in Figure L-30	Ideally, this would be the same so that flow rate adapters would be interchangeable between FRMs and continuous methods.

Surface Finish	7.3.7	Anodized aluminum for all internal surfaces exposed to sample air prior to the filter.	Ideally continuous methods will also have anodized aluminum for all internal surfaces exposed to sample air prior to the filter or surrogate collection device. This is especially important to note for cyclones; if used, since they are not part of the FRM.
Sampling Height	7.3.8	2 meters ± 0.2 meters	Ideally, the sample inlet on a continuous method would meet this.

Performance Specifications

Performance specifications for the FRM are largely associated with maintaining the flow rate within an acceptable range and the operational conditions for which the instrument should be capable of operating in. Most of the flow rate performance specifications for the FRM should be applicable to continuous methods; however, the operational conditions for which an instrument should be capable of operating in may or may not be applicable to any one continuous method. Many of these performance criteria can be applied to a potential continuous method. Most of the commercial vendors of PM continuous methods have already incorporated these performance criteria into their instruments. The table below describes the various performance specifications for the FRM and their applicability to PM continuous methods. Also, where appropriate, alternatives to the FRM performance specifications are offered:

Performance Specification Area	Section of Appendix L	FRM specification	Applicability to Continuous Methods
Sample Flow Rate	7.4.1	16.67 L/min measured as actual volumetric flow rate at the temperature and pressure of the sample air entering the inlet.	Generally applicable with the exception of any potential use of nephelometers. This flow rate is necessary if a PM_{10} size selective inlet is used as well as for most second stage separators.
Leak Test Capability	7.4.6	Provide for an convenient external leak test capability	Generally applicable.
Range of Operational Conditions	7.4.7	Ambient Temperature - 30 to +45 C Ambient Relative Humidity 0 to 100 percent Barometric Pressure 600 to 800 mm Hg	Generally applicable as a starting point for design of an instrument; however, some continuous instruments may need to be located in an environmentally controlled shelter in order to have operate correctly. Some instruments may not meet all of these specifications which may limit their use geographically.
Ambient Temperature and Barometric Pressure Sensors:	7.4.8 and 7.4.9	Capable of operating over the range of operating conditions	Applicable for the operation of the continuous instruments in the range of environmental conditions they will encounter.
Filter Temperature Control	7.4.10	The sampler shall provide a means to limit the temperature rise of the sample filter from isolation and other sources to no more than 5C above the temperature of the ambient air surrounding the sampler.	It is desirable to minimize the temperature difference between the ambient air and the location where sample are collected and analyzed in a continuous method to provide for minimal volatilization of PM; however, in some cases heating may be necessary due to moisture interference or other reasons. Each potential continuous method should be designed to optimize this temperature difference with respect to avoiding moisture interference, PM volatilization, and stable measurement readings.

Filter Temperature Sensor	7.4.11	Capable of operating over the range of operating conditions	Generally applicable. However, may not always be necessary depending on the measurement principle of the continuous method.
Clock/timer system	7.4.12	Capable of maintaining local time and date including year, month, day of month, hour, minute, and second to an accuracy of ± 1.0 minute per month.	Generally applicable.
Outdoor Environmental Enclosure	7.4.14	Suitable to protect the instrument	Generally applicable for those instruments intended to be located outside. Not necessarily applicable to those instruments intended to be located in a station trailer or other environmentally controlled housing
Electrical Power Supply	7.4.15	105 to 125 volts AC (RMS) at a frequency of 59 to 61 Hz.	Generally applicable.
Data Output Port Requirements	7.4.17	Standard RS-232C	The Standard RS-232C data output connection can be utilized. Additionally, it is strongly encouraged to have a provision for an analog output that can be conveniently connected to a typical data logger utilized by ambient air monitoring agencies. For example, 0 - 10mV, 0-100mV, 0-1V, 0-5V, or 0-10V.

Section 10. Linkage to national monitoring strategy

The EPA in partnership with it's principal grantees; States, Local agencies and Tribes, are formulating a national air monitoring strategy that strives to enhance the overall effectiveness of major regulatory based monitoring efforts throughout the nation. The continuous PM monitoring plan addressed here is a major part of that strategy.

The monitoring strategy provides a future direction for air quality networks throughout the United States. This direction incorporates knowledge acquired in air quality research and management practices over the last two decades, and takes advantage of the existing infrastructure of operating networks and monitoring agencies. The experience over the last 20 years suggests three basic enhancements in national network design:

1) ***Promote multiple and collocated pollutant measurements*** to improve how we diagnose cause effect phenomena in health effects and air pollution studies.

2) ***Improve regional scale air quality characterization*** to understand the linkage between background and transport concentrations (regional, continental, global scales) as they impact both rural and urban environments, an increasingly important need as the separation between rural and urban air pollution levels continues to decrease.

3) ***accommodating new technologies*** to provide timely reporting of air quality information to the public and to improve basic characterization of physical, chemical, temporal and spatial composition of air quality.

Consistent with these enhancements, the strategy has identified needed improvements to the monitoring program:

- characterization of hazardous air pollutants (HAPs);
- continuous particulate matter monitoring;
- information transfer and delivery;
- integration across pollutant programs; and
- optimization of the existing criteria pollutant monitoring networks.

This continuous monitoring implementation plan details EPA's proposal to optimize the PM components of the monitoring network. The broader vision for a PM network would use more continuous operating samplers and fewer filter-based samplers than the current system. The current $PM_{2.5}$ network of approximately 1100 integrated samplers (FRMs) and 200+ continuous samplers should evolve into a system of perhaps 700- 1000 $PM_{2.5}$ samplers with a more even distribution (e.g., 50-50) of integrated and continuous methods. The continuous methods must be integrated to ensure data compatibility with the current FRM network. The challenge in this strategy is to maximize the benefit of continuous samplers by allowing continuous monitors to be used for many applications including regulatory use.

Section 11. Regulatory Changes and Schedule

There are a number of federal regulations that are used to provide the framework for ambient air quality monitoring. These regulations cover the sampling and analytical methods used, how new methods are approved, quality assurance and control procedures, and basic monitoring objectives for certain air pollutants. Technical information is provided in guidance documents and through the Internet.

Specific Regulations to be Reviewed:

There are three main regulatory "Parts" of the Code of Federal Regulations (CFR) that we intend to modify. These regulations are all part of CFR Title 40 which deals with the environment. Specifically:

40 CFR 50[11] Appendices: National Primary and Secondary Ambient Air Quality Standards (NAAQS), Appendix L. This regulation provides us with the NAAQS and the federal reference methods for measuring each air pollutant with an established standard. We are NOT going to modify the national ambient air quality standards with this regulatory review. Reviews and, if needed, revisions of the NAAQS occur in separate formal processes. We do want to review a portion of the minor requirements in the Appendix L portion of this regulation which describes the reference method for measuring $PM_{2.5}$. The overall reference method will not be modified; however, we do want to examine some of the requirements for reporting supplementary data on the samplers' performance. We have successfully completed two annual quality assurance reports on the $PM_{2.5}$ FRM network operation, and we believe that we can reduce the amount of supplementary data being reported to EPA, specifically in Table L-1. This is a small change; however, it may provide some relief to State, local, tribal, and other monitoring agencies' data managers.

40 CFR 53 Ambient Air Monitoring Reference and Equivalent Methods. This regulation provides air quality monitoring instrument manufacturers with the application and testing requirements for reference and equivalent methods that must be followed in order to have their sampler/analyzer approved for regulatory use. The EPA's Office of Research and Development (ORD) is currently responsible for these approvals. This regulation describes the complexities of how new criteria pollutant methods can be formally introduced into the ambient air monitoring network. EPA is a strong proponent of this formal process given the policy and financial impact that decisions using data from federal reference and equivalent methods can carry. We will review this regulation; however, changes to it may or may not be taken in this package. The particulate matter National Ambient Air Quality Standard is being reviewed separately by the EPA. This separate process will also be used to promote continuous particulate matter monitoring technologies within our regulations.
The EPA's ORD has established a Reference and Equivalent Method Board that includes members from OAQPS and ORD. This Board's function has been to review new and modified proposals for fine particulate matter monitoring candidate methods, and to provide broader program input into the approval process. OAQPS proposes to expand the

[11] Regulations are cited in documents using the format "Title# CFR Part#".

role for this Board to include identifying how to incorporate regional equivalency into the existing reference and equivalent method testing program prior to any actual regulatory change. This approach may need to take the form of a pilot project initially. We will also need to examine our regulatory authority for making such a change. There is a precedent for approving regionally based equivalency within the particulate matter program, specifically with the approval of the Oregon DEQ Med-Vol sampler. It will be necessary to follow-up with any regional equivalency process with formal regulatory changes to Part 53.

40 CFR 58 Ambient Air Quality Surveillance. This regulation is a primary focus of our efforts to both incorporate new technologies and to provide data as outlined in the national monitoring strategy. Nearly all data collection and reporting requirements, all the quality assurance requirements, the NAAQS pollutant network design criteria, the air quality index reporting, and annual data certification requirements are included within this regulation. This regulation describes how the Clean Air Act air monitoring authority has been interpreted and implemented by the EPA and our State and local agency partners for air pollutants with established NAAQS. Tribal agencies are not regulated under this provision; however, the technical requirements within should be familiar to any tribal agency that plans to conduct monitoring.

We expect to change the 40 CFR 58 regulations to allow more flexibility in designing the particulate matter monitoring network. One of these changes would include modifying the existing correlated acceptable continuous (CAC) particulate matter monitoring approach to allow for a more network-based approach rather than only the site-by-site approach as defined currently. The original CAC provisions were developed prior to the full deployment of sequential federal reference methods (FRMs) for fine particles as a way to provide sampling frequency relief from daily sampling. Since the sequential FRMs have been available and are working, the CAC provision has largely been ignored by air monitoring agencies. EPA will modify this provision so that it will provide a better mechanism for incorporating continuous particle monitors into the network.

Participants in the Regulatory Review

We have solicited input from a variety of parties for this regulatory review process. Through the larger air monitoring strategy, we have created a National Monitoring Strategy Committee that is providing advice and recommendations for the national air monitoring program. Some of these recommendations will be realized only after regulatory change has taken place. The NMSC has been discussed in section 10 of this document.

We have also created three separate work groups, one each for the subjects of regulatory review, quality assurance, and technology. These work groups were established to make some concrete progress on the program changes needed to realize the national monitoring strategy goals. The quality assurance group will provide recommendations for changes to the quality assurance provisions of the monitoring regulations as well as all existing quality assurance practices; and the technology work group will make recommendations for use in the methods sections of the regulations and in technical guidance used by monitoring agencies. The regulatory review work group must take information from all of these parties, in addition to the NMSC and the work group's own recommendations, and develop an appropriate regulatory package.

The NMSC and the three work groups include representatives from the EPA OAQPS, the ten EPA Regional Offices, State agencies, local agencies, and tribal governments. All regulatory changes will undergo public review and comment inherent within the regulatory modification process. EPA will also work through existing mechanisms such as the STAPPA/ALAPCO Monitoring Committee and the Standing Air Monitoring Work Group (SAMWG) to communicate with stakeholders on these regulatory changes.

Schedule

The National air Monitoring Strategy identifies the need to review and revise the federal monitoring regulations in order to create an air monitoring system that is responsive to current and emerging environmental data needs. Along with a variety of topics, we intend to review and modify these regulations to incorporate more continuous particle techniques. The proposed monitoring strategy regulatory changes are being incorporated into the PM NAAQS review and this schedule reflects this merging of rule-making actions.

Key Milestones (later milestones are subject to change):
October - NMSC recommendations on the national network.
October 23-25, 2001 - Monitoring Strategy Workshop
December 2002 - Draft rule-making language prepared for work group review.
June 2003 - Proposal in the Federal Register
July-September 2003 - Public comment period
October - December 2003 - Review public comments, prepare responses
January 2004 - Final regulatory package published in Federal Register

Section 12. Summary of Issues and Action Items

This document serves as a bridge between concepts for integrating continuous PM monitors presented at meetings with the Clean Air Science Advisory Committee's Subcommittee on Particle Monitoring in January, 2001 and January, 2002 and comprehensive guidance for monitoring agencies. There remain numerous details not addressed at this time that should be addressed to ensure a satisfactory outcome. These issues and other areas of concern include:

- ***Complex program***. The concepts and elements incorporated in this plan are singularly and collectively complex therefore creating a communications challenge. Other approaches were considered, but the potential drawbacks of a simplistic approach were not acceptable. That is, it would have been easy to develop a rigorous non-flexible program easily communicable but conveying little motivation for deployment. Similarly, a program without constraints would likely compromise data quality and interpretability. Thus, a decision was made to accommodate both flexibility and data comparability at the expense of developing and communicating a complex program.

- ***Rescinding REM certification based on future poor performance***. The REM program is based on demonstrating an acceptable level of comparison between FRM and continuous samplers. This relationship may change as a result of atmospheric changes due to deployment of emission mitigation strategies. Guidance, albeit complex, will allow for a non static relationship. Nonetheless, this potential for aerosol change will require iterative evaluation of instrument performance that is likely, in some instances, to show that a previously approved REM fails performance goals.

- ***Developing and approving regional equivalent domains***. The information in this document can be applied in a somewhat straightforward manner for approving an instrument for CAC or REM purposes at an individual site. The larger goal is to broaden this acceptance to a "region" where the meteorological and aerosol composition characteristics exhibit consistent behavior and hence throughout which the continuous and FRM methods exhibit similar relationships. Regionality is further complicated by administrative and demographic issues (e.g., multiple monitoring agencies and State boundaries intersecting within a given "region"). To simplify implementation, the proposal in this document is to start with approval across an entire State. Multiple States may seek approval in a coordinated effort or a State may need to be broken down into smaller sub-domains. Geo-political boundaries can have the have the advantage of a consistently implemented monitoring program (One state monitoring agency having oversight for all monitoring operations within that state); however, regions of performance are more likely associated with the homogeneity of the aerosol encountered. This may be larger or smaller than the domain of a state.

- ***Reliance on FRM measurements as an indicator***. The underlying approaches require comparability of continuous and FRM measurements. The reason for this is that so many objectives relate to the FRM measurement (e.g., NAAQS comparisons, AQI, air quality model application). In many instances, there is no technical reason to expect comparability between disparate measurement approaches. Such comparability is desired given the utility of relating continuous measurements to a wealth of existing FRM data and to incorporate a reference marker. The downside of this approach is that the value of an

FRM measurement is assumed or inferred to be greater than that of a candidate method, when in some cases the candidate method may better reflect "true" characteristics of an aerosol.

- ***Specific Guidance on Performance Specifications***. Sections 5 - 8 introduce performance specifications for bias, precision, and correlation but several specific details are not addressed. For example, how is bias measured? What is the statistic as well as what is the source of the data to be used in the statistic? Are bias estimates based only on existing collocated instruments or is an independent audit required? How are bias and precision treated on a regional basis, does the failure of one site constitute failure for a region, or are all estimates averaged across a region? What is the appropriate frequency for checking bias and precision? These unique considerations warrant development of a dedicated Quality Assurance program for CAC and REM applications.

- ***Integrating Correlation with the PM2.5 DQOs***. Section 6 presented an initial attempt to identify correlation criteria for CAC and REM. The basis for the correlation criteria presented includes: evaluation of the existing network; expected sample size for a years worth of data at a routine site; identification of a desired *true* underlying correlation, and selection of tolerable error rates. At this time it is not known how integrating a correlation criteria would affect the PM2.5 DQO's. More work will need to be performed to integrate correlation with the PM2.5 DQO's.

- ***Data interpretation and management***. Transformed data are to be submitted to AIRS. How do analysts gain access to raw non-transformed data? Transformation models are based on 24-hr comparisons, yet transformed data will be reported continuously, which may create odd results in discrete hourly reporting. Coding specifications for CAC and REM need to be developed.

- ***Demonstration of performance***. The bias and precision estimates are based on existing network performance. This implies that the testing to meet such specifications should be conducted under conditions consistent with routine operations. This approach should not be interpreted as excluding desired vendor participation. Responsibilities for conducting testing, developing transformations and communicating performance results requires further effort.

- ***Consistency with FEM***. The current Class III equivalency requirements appear to be more strict than what a FRM can meet. That is, the imprecision in the FRM is such that the correlation requirement can not be met, not because of the challenging instrument, but because of the instrument being used as the standard. This inconsistency needs to be addressed. In doing so, it may make it possible for an instrument to acquire a Class III equivalency. Work will be initiated to evaluate the necessary performance criteria for national Federal Equivalency based upon a DQO approach.